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Measurement Techniques

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LINEAR MEASUREMENTS

WRINGING EFFECT IN BLOCK GAUGES

V. A. Solov'ev

Translated from Izmeritel'naya Tekhnika, No. 4, pp 1-4 April, 1960

This article describes the work of the Interchangeability Bureau in finding the factors which affect the cohesive force between block gauges and determining an objective criterion for a wringing fit.

For this investigation 320 block gauges between 1 and 100 mm were chosen and carefully checked for their dimensions, flatness, curvature, and roughness to an accuracy of $2 \cdot 10^{-6}$ mm. The flat plates for interference measurements were of the 1st grade of accuracy. The investigation was carried out according to the following technique: the measuring surfaces of the gauges were cleared of the surface film by means of benzene, ether, alcohol (methyl, ethyl, and propyl) and benzine; the dissolved film was removed from the measuring surface of the gauges by means of absorbent cotton wool previously cleared of any greasy impurities; the degree of surface cleanliness, and freedom from impurities and grease films was judged by wetting the surface with water and by the degree of surface adhesion; the flatness and the dimension of the gauges before and after they were fitted together, were measured on an interference comparator, and the roughness of the measuring surfaces on a micro-interferometer and a profilograph; the lubrication layer was applied during the final lapping of the measuring surfaces, and after the gauges were made an additional lubrication layer was applied by the drop method using kerosene, vaseline oil, and solutions in benzine of stearic, lauric, and oleic acids; the measuring surfaces were rubbed with a towel soaked in the above substances and with a towel containing traces of grease and soap; the gauges were lapped to a block or to checking glass plates mechanically or by hand; the normal and tangential resistance forces were determined on special instruments.

First the gauges were washed in benzine and then degreased in benzene.

Measuring surfaces which were cleaned in benzene could not be wetted by water or made to adhere to other surfaces, yet those cleaned in ether or alcohol preserved their wringing properties, but their cohesive force decreased.

Gauge blocks which were washed in benzine alone were wiped in a clean cotton towel and each group of gauges was then checked for a wringing fit. The numerical values of the tangential resistance forces are given in a graph (Fig. 1 and 2). The experiments were then repeated with the same gauges covered with a layer of grease before lapping by the method described above. Their numerical values of the tangential and normal forces are given in Fig. 3.

The wringing effect and the resistance forces were determined in the following manner: a) by placing manually one gauge on top of another (rubbing in); b) by sliding manually one gauge on top of the other; c) on a special instrument for building up gauges into blocks and determining their normal resistance forces which are a measure of their tendency to wring; on this instrument the lapping consists of turning the table of the instrument through 90° together with the lower glass plate and the gauge, attached to the plate by a wringing fit, with respect to stationary gauge held by wringing to the upper glass plate; d) on a special instrument for lapping gauges by sliding one gauge on the other and determining the tangential resistance force which is a measure of the gauges' ability to wring; on this instrument the lapping consists of a to and fro movement with respect to the fixed gauge along the gauge cam wrung to the glass plate which is fixed to the instrument's sliding rotary disk.

In all these instances, with the exception of the first one, lapping ended in the formation of an intermediate layer and a firm cohesion of the lapped surfaces. The placing of one gauge over the other did not provide complete wringing.

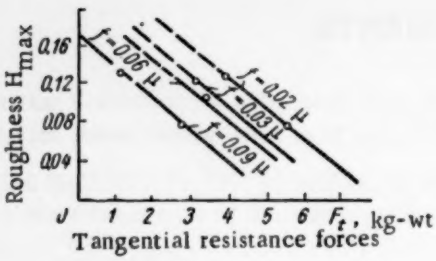


Fig. 1.

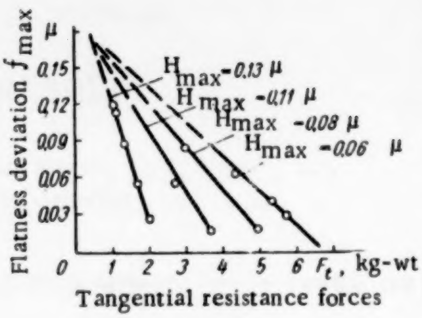


Fig. 2.

The cohesive force was determined by means of the same instrument. It was established that cohesion between lapped surfaces both for mechanical and manual lapping is determined by forces which are numerically close to each other and grow with decreasing macro- and microirregularities of the measuring surfaces (Fig. 1 and 2).

It is only natural that when gauges are lapped to glass checking plates or between themselves, those places which have the thickest film come first into contact with each other and then to a certain extent cohere. With subsequent pressing of the gauge against the plate the lubrication layer is extended to relatively free places in the gaps between the lapped and unlapped surfaces and fills them. With further lapping the two lapped surfaces can no longer be separated. The lapping ends at the moment of the "yield", at which the external effort applied to the gauge for lapping can no longer move the cohering gauges. This is the moment when lapping is completed i.e., the moment of the "yield". This instant determines the existence of a firm contact between the surfaces and indicates that the surface lubrication layer of the lapped surfaces has reached its maximum contact area. Any further attempts to move the lapped plate on the gauge lead to a weakening of the cohesion of the surfaces and disrupt the cohesive surface layer. It should be noted that owing to the lack of flatness either in the gauge or in the plate, a tight and firm wringing fit does not always occur. When this happens, lighter spots of different shades appear on the surface of the gauges.

Darker spots and shades appear on gauges which are lapped to the plates and have small scratches. In other instances the shades and spots are blurred and shapeless. This means that between the lapped surfaces there is an unevenly distributed thick layer of lubrication. Under these conditions any method of building up gauges into a block will not ensure an identical firm and complete contact and, hence, it will be impossible to complete the lapping process. In such cases there will always be deviations from parallelism, flatness and the mean length of the gauge block.

A contact which is not entirely complete or firm can also occur between the gauge and the plate when wringing has been achieved. This effect shows that there are free places which are not cohering, and the lubrication layer which cover these portions do not touch each other owing to their thinness and therefore cannot ensure cohesion. Should the free portions be covered with a lubricating layer up to the level of cohesion, by increasing the thickness of the lubricating layer, the cohesive force will not rise, but remain small, similar to the case of a thicker lubrication layer whose cohesion zone approaches the nominal area of the gauge's measuring surface. Approximately the same results were obtained experimentally when gauges whose measuring surfaces had a relatively larger roughness H_{max} = 0.13 μ were used with any thickness of the lubrication layer (Fig. 1).

When the gauge-measuring surface touches the plate in separate zones only, and lighter spots and shades can be observed in places where the cohesion layer is at its minimum, or the measuring surfaces touch each other by their protrusions only, the cohesive force developed by the border layer will be as small as with thick lubrication layers. Such wringing of the gauges can be called partial wringing.

When the cohesion area approaches that of the nominal measuring surface of the gauge and the thickness of the lubrication layer in the cohesion zone does not fall below a certain value (0.01-0.03 mm), the wringing will be complete and the cohesive force produced by the border layer will be at its maximum.

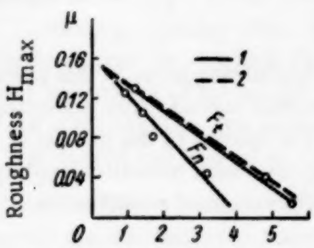
In checking the wringing effect and determining the normal resistance forces of a gauge block it was established that: a) end gauges from 1.6 mm up become deformed on separation (their deviation from flatness

in the free state increases by 0.3-1.0 μ); b) the separation produces in many instances a disruption of the surface layer; c) since the establishment of the relationship between the wringing effect and the normal resistance forces is difficult, the tangential force was taken as the criterion of the wringing effect expressed in terms of the minimum numerical value of the force for which two end gauges lapped into a block still hold together.

The movement with static friction is also impeded to a considerable extent by the contact between metals.

When the measuring surfaces of the gauges have a thin lubrication layer and come into contact under the force exerted in lapping, the size of the metallic contact is greatly decreased. Owing to plastic deformations and the effect of the forces of attraction inside the thin lubricating surface layer, the measuring surfaces of the gauges will come close together and, with a high pressure at the points of contact, may break the surface layer. This contact corresponds to the metallic contact between the measuring surfaces at which lapping should end and a certain "yield" in the lapping force appears, a "yield" characteristic for determining the maximum force of attraction of gauges built into a block.

Any further attempts to move the lapped surfaces of the gauges will only lead to the breaking away of one surface from the other. The breaking away of the gauges and the degree of disruption of the surface layer associated with it and the damaging of the surface metal (scratches) depends on the nature of the lubricating layer and the character of the microirregularities of the metal. The size and nature of the scratches does not affect wringing, yet an increase in the number of such scratches can decrease and finally completely stop cohesion. The size and nature of the scratches formed as the result of the metallic contact of one measuring surface with another differ considerably from those formed through damage by an external body.



Tangential resistance forces F_t, kg-wt
Normal resistance forces F_n, kg-wt

Fig. 3. 1) After lapping; 2) after lubrication by vaseline oil.

Lapping of measuring surfaces of gauges produces coupling forces which can be divided into three categories: forces of molecular interaction inside the surface layer (cohesive coupling); forces of attraction between surface layer and the surface of the solid body (adhesive coupling); and forces of linkage between two solid bodies.

With a relatively thick surface lubricating layer (over 0.15 μ) which covers completely the protrusions and hollows of the microirregularities of the measuring surface, the gauges are easy to lap but the resistance forces which hold the gauge block together are small (up to 0.4 kg-wt/cm^2).

In gauges with a relatively thin surface layer (less than 0.05μ) both a cohesive and adhesive force of interaction is observed. The wringing effect in gauges varies (from 0.8 to 3 kg-wt/cm^2). The tendency to wring decreases with a rising roughness of the surface, and coupling stops with a roughness of $H_{max} = 0.15\ \mu$.

For lubrication layers thinner than 0.02 μ all the three types of coupling are observed.

Experiments have shown that it is impossible to obtain firm coupling and a constant size of the block if the gauges have different sizes of microirregularities and the lubricating layer was smeared on just before the gauges were lapped into a block. If a lubricating layer is smeared on clean measuring surfaces before they are lapped into a block, such surfaces will wring but the forces of resistance developed by the surface layer will be smaller than in the case of a film formed during the manufacture of the gauge.

Lubricating layers smeared on the surfaces before building up a block lubricate the surface badly, stick to it insecurely, and are washed away by the first regular washing and cleaning of the surface by means of solvents. Lubricating layers smeared on the measuring surfaces of gauges in the manufacturing process in the form of a thin film of oxides and lathers are formed by rubbing in liquid lubricants under definite conditions of lapping. Such films adhere securely for a long time to the surface of the metal in the presence of vaseline oil, are not washed away by solvents, and are of considerable practical interest. In this case the forces of resistance produced by the surface layer depend not only on the nature and thickness of the lubricant, but also on the character of the measuring surface.

It should be noted that all types of microirregularities of measuring surfaces cannot hold securely lubrication layers produced during manufacture.

If the manufacturing process is designed only to decrease the height of the crests (a higher grade of finish) or only to decrease the hollows between the crests (packing of microirregularities) of the measuring surfaces, the actual contact area with the lubrication impregnated between the microirregularities will increase. Experiments have shown, however, that the cohesive forces produced by the surface layer grow quicker if the width of the hollows and the height of the crests is reduced at the same time. Technologically this can be achieved.

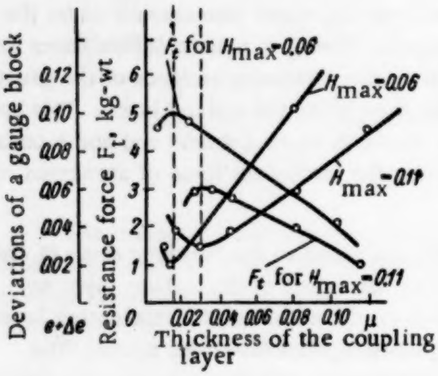


Fig. 4.

Microirregularities with narrow and shallow hollows serve as microreservoirs for lubricants. During washing and cleaning superfluous lubrication is removed from the measuring surfaces of the gauges; the solution of the lubricant which remains in the hollows of the microirregularities becomes more liquid.

During lapping the molecules of this solution, being in a liquid state, migrate between the coupled measuring surfaces and produce, in the form of a thin, durable film, a layer which ensures the cohesion of the gauges.

The thickness of the surface lubricating layer in this instance amounts to 0.01-0.03 μ (5-10 molecular layers). The disruption of the lubricating layer occurs in small localized areas. The metallic coupling thus formed in the process of lapping through the lubricating layer raised the coupling forces only partially (Fig. 3). Such metallic coupling is almost completely responsible for wear and damage to the measuring surfaces (formation of scratches) especially at the instant the gauges are separated.

Following the tests, gauges were checked for dimensions before and after building up the block and the resistance force of the gauge block was determined. The test results are shown in Fig. 4. It will be seen from the curves that the deviation of the length and the resistance force depend not only on the thickness of the greasy surface layer, but also on the roughness of the measured surface.

SUMMARY

1. The thickness of the surface films formed during production decreases in a regular manner with decreasing roughness and with a roughness between 0.03 and 0.06 μ provides stable dimensions for gauge blocks.

2. It appears that 0.02-0.03 μ is a critical value for roughness, and that if it is decreased during lapping in building up a block, a firm and close coupling is obtained, which, however, may lead to seizing (jamming) and the formation of a cold welded seam (speedy deterioration) on the measuring surface of the gauge, and if the roughness is increased, it leads to a loss of the wringing effect and a rise in the dimensions of the gauge block.

3. The tangential resistance force may serve as a criterion of the tendency to wring.

4. A specified method of lapping end gauges should be included in the instructions for checking them.

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*See English translation.

MEASURING THE LINEAR TEMPERATURE COEFFICIENTS OF BLOCK GAUGES BY PHOTOELECTRIC MEANS

E. A. Volkova and Yu. P. Efremov

Translated from Izmeritel'naya Tekhnika, No. 4, pp 4-7, April, 1960

Block gauges are often used for precision work at temperatures distinct from 20°C. The linear temperature coefficient α must, therefore, be known with a high degree of accuracy.

Block gauges are made of tempered steel of special composition. A tentative value of the temperature coefficient can be obtained with a low degree of accuracy from a sample of a given steel casting. In heat-treatment and ageing of the gauge, the temperature coefficient α changes due to the variation in the internal stresses of the material [1]. The temperature coefficient can, therefore, be measured accurately only on the gauge itself if it is heated and cooled as little as possible in order not to change its structure.

The Fizeau method has been improved in recent years; the instrument is supplied with a device which records the coefficient α at temperatures up to +185°C [2] and polarized light is used [3].

Over small temperature intervals the errors inherent in the Fizeau method affect considerably the measurement results, hence this method cannot be recommended for precision measurements of the α coefficient of block gauges.

The D. I. Mendeleev All-Union Scientific Research Institute of Metrology has developed an interference method of measuring coefficient α. This method was applied by means of an instrument constructed on the lines of a Michelson interferometer [4, 5]. One of the main parts of the instrument consists of a heater made of a horizontal cylinder with a heating winding and a coil pipe for flowing water. The gauge 30-100 mm long with a glass plate (40 × 15 × 7 mm) lapped to its measuring surface is placed in the middle of the heating cylinder. When the instrument is illuminated by means of a cadmium lamp with a green filter, two systems of interference fringes of equal width become visible in its field of vision. As the heater is switched on a relative displacement of interference patterns is observed. According to the technique described in [4] the fractional part of the interference sequence is noted every 2-3 minutes from visual observation. Since one cycle of these measurements lasts up to 2 hr, this method is rather labor-consuming and it is therefore advisable to use photoelectric recording for measuring the increment in length.

The Institute's method of photoelectric recording of interference fringes of equal inclination is used in measuring the Fabry-Perot standards of length and for spectral lines investigation [6, 7]. This method can also be used for recording interference patterns with fringes of equal widths, and it was used in the interferometer for measuring the coefficient α. The receiving device was illuminated by a luminous flux restricted by a narrow slit which was parallel to the fringes and separated parts of the interference patterns of the gauge and the auxiliary plate. The insufficient illumination of the receiver, however, prevented clear recording. An increase in the width or the length of the slit is not advisable since the block gauge deviates from flatness and parallelism up to 0.15 μ (OST 85000-39) in the case of second-grade gauges 100 mm long, and this deviation amounts to 0.5 of a fringe width. The errors in the manufacture of gauges make the interference fringes at the surface of the gauge inclined with respect to the fringes produced by the plate. The slant of the fringe produces a considerable error in the recording of the displacement of the interference patterns.

More favorable conditions for photoelectric recording are obtained with equally inclined fringes. In order to use equally inclined fringes, flat plates of the same size as before were lapped to both measuring surfaces of the gauge so that their surfaces formed a standard of the Fabry-Perot type.

In choosing the dimensions of the plates we aimed to make their thermal capacity smaller than that of the gauge, yet to make them sufficiently thick to prevent distortion of the plate surfaces on heating. The free surfaces of the lapped plates were covered with a silver layer which had a reflection coefficient of approximately 65% and a transmission factor of 25%.

Figure 1 shows the gauge with the two plates lapped to it and placed with its long side over four tapered rods fixed to a stand, which is placed inside the heating cylinder.

As a result of the instrument's conversion, a new equipment was obtained whose diagram is shown in Fig. 2. The light passes from the source, a cadmium lamp with an incandescent electrode 1, through lens 2 to monochromator 3, whose output slit fits that of the collimator 4; and falls on the flat plates lapped to gauge 6, which is place in heater 5.

Having passed through lens 7 the light falls on photomultiplier 8 (FÉU-19), which is fed from rectifier 14 VS-9). By means of the photomultiplier and the photocompensating amplifier 11, 12, and 13 (F-16) the luminous flux from the central portion of the interference rings of equal slant is recorded.

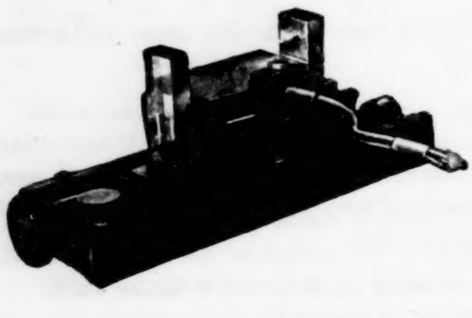

Fig. 1.

The equipment was tested out by repeated measurements of the linear temperature coefficient of a gauge block with a nominal length of 50 mm. The gauge was placed in the heater whose inspection window had a slit diaphragm measuring 7×3.5 mm fixed to it. The diaphragm separated out a portion of the Fabry-Perot standard over which the deviation from parallelism did not exceed 0.1 of the interference fringe. The collimator slit was narrowed to such an extent that the photomultiplier did not receive more than 0.2 of the central interference ring. The temperature of the gauge was measured by means of thermometer 10 and a thermocouple with galvanometer 9. The thermocouple junction was pressed against the middle of the gauge by means of a bracket.

After a certain time had elapsed the heater was switched on and controlled by means of a rheostat, for a smooth rise in the temperature of the gauge.

The heating of the gauge leads to a change in the interference sequence in the center of the rings with equal slants and, hence, to a variation in the luminous flux which passes through the separated-out portion of the interference pattern. As the result of this effect a series of maxima and minima appear on the recorder tape.

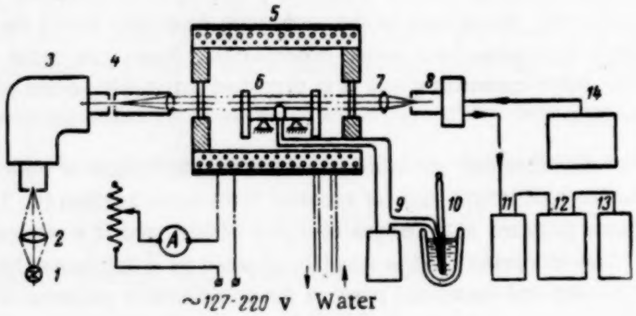

Fig. 2.

When 5-10 maxima had been received, the current in the heater was switched off, and when the recorder showed that the dimensions of the gauge had remained constant for 10-15 min (the recorder pen having drawn a horizontal line) the cycle of one measurement was completed. It was considered that the initial and the final temperatures of the thermocouple are equal to the mean bulk temperature of the gauge.

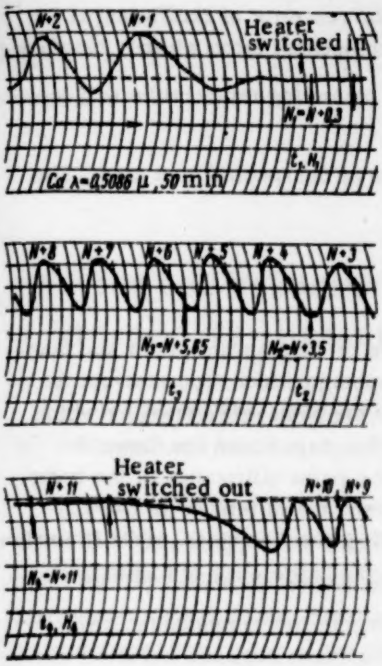

Fig. 3.

During recording in certain places of the graph, the temperature was measured, and at the beginning and the end of the cycle the pressure was read on the barometer. Figure 3 shows one of the graphs divided into three parts. Here N + 1, N + 2, N + 3, etc., denote consecutive interference sequence integers recorded during the heating of the gauge; t_1, t_2, t_3.. are temperatures taken at instants corresponding to the arrows directed upwards; the arrows directed downward correspond to instants when the heater current was switched on or off.

The table shows the temperature, and pressure readings and the corresponding interference sequences of the graph in Fig. 3.

For the calculation of the increment Δl of the gauge length the following formula was used:

$$\Delta l=(N_2 - N_1)\,\frac{\lambda}{2} + [0{,}938\,(t_2-t_1) - 0{,}361\,(H_2-H_1)]\,10^{-6} l,$$

where N_2-N_1 is the change in the interference sequence; t_2 and t_1 are the temperatures at the instant of observation which correspond to the interference sequences N_2 and N_1; H_1 and H_2 are atmospheric pressures at the beginning and the end of the observations, mm Hg; and l is the nominal length of the gauge, mm.

The two terms of the formula included in square brackets represent corrections for variations of the difference in light paths due to changes in the air temperature and pressure.

Temperature, °C	Interference sequences	Atmospheric pressure according to the barometer, mm Hg
23.10	$N_1 = N + 0.3$	754.7
24.80	$N_2 = N + 3.5$	–
25.77	$N_3 = N + 5.65$	–
27.73	$N_4 = N + 11.0$	754.8

The above method of recording the extensions makes it possible to calculate by means of one graph both the static and dynamic values of coefficient α. From the above table the following values of α were obtained: for points 1 and 4, $\alpha_{1,4} = 12.1\ \mu/\text{m} \cdot$ degree in the static condition; for points 2 and 3, $\alpha_{2,3} = 12.2\ \mu/\text{m} \cdot$ degree for the dynamic condition.

It is possible to use the dynamic condition only when [4] the temperature of the gauge and its length vary smoothly: when the maxima on the graph are equally spaced.

The error in determining coefficient α depends on the value of the errors in measuring the increments in the length and the temperature.

The utilization of the dynamic condition presupposes the existence of certain temperature gradients between the surface and internal layers of the gauge, gradients which produce interference fringes distortions, whose magnitude depends on the construction and thermal condition of the heater. This condition also determines to a certain extent the value of the temperature-in crement measurement errors.

In the equipment under consideration the recording of the interference pattern at a corresponding heating condition provided a measure of the increment in the length with a root-mean-square error of the order of $0.03\,\alpha$, and that in the temperature with an rms error of 0.025°C.

The working out of the results of five measurement cycles showed that the rms error of coefficient α for the given gauge was of the order of 0.2 μ/m · degree, thus agreeing with the component errors already mentioned.

A more even thermal condition of the heater and increased accuracy in measuring temperature will provide, it would appear, a considerably higher accuracy in measuring coefficient α.

The length l of the measured gauge is restricted by the coherence limits of the spectral line used. The coherence limit is determined by expression

$$2l = \frac{1}{\omega}\,\mathrm{cm},$$

where ω is half the width of the spectral line used, in cm^{-1}. The imperfections of the standard plates and deviations from parallelism between them as well as the finite dimensions of the diaphragm which separates-out the recorded portion of the interference pattern, lead to an even larger decrease in the paths' difference for which it is possible to apply the interference method with photoelectric recording. Thus experience has shown that for the cadmium green line (λ = 0.5086 μ) similar measurements can be made for a paths' difference of the order of 150 mm, i.e., for gauge lengths of 75 mm. When the cadmium red line is used, the difference in paths $2l$ must not exceed 250-300 mm. The use of the infrared line of isotope Kr^{86} will, it would appear, make it possible to measure, by means of this method, gauges up to 300 mm long, since with a path 'difference of 650 mm the interference fringes were clearly recorded for six infrared lines Kr^{86} [8].

SUMMARY

In measuring the linear temperature coefficient of end gauges it is expedient to use, for determining increments in length, the interference method with photoelectric recording which makes it possible to decrease the labor consumed by the measurements and raise the reliability of the results.

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*See English translation.

A DEVICE FOR CHECKING LEVER GAUGES AND SCREWS IN MICROMETERS MEASURING OVER 200 mm

N. K. Ochinskii

Translated from Izmeritel'naya Tekhnika, No. 4, pp 7-8, April, 1960

The Zaporozh State Inspection Laboratory for Measuring Equipment has developed and brought into use a special attachment for checking lever gauges measuring over 25 mm.

The advantage of this attachment consists in the fact that it is not necessary to move the anvil of the gauge for either fixing or removing the attachment.

Its frame 1 (Fig. 1) is made from a tube section. Rod 2 is permanently fixed to one end of the tube. The second expanded part of the tube carries, in grooves which are at an angle of 5° to the axis, a freely moving brass roller 3.

In order to fix the attachment the sliding roller should be moved toward the left, the hood slipped over the protruding part of the adjustable anvil and fastened to it by moving the roller toward the right. The error of the lever indicating gauge is measured by placing block gauges between the sphere of the rod and the moving anvil.

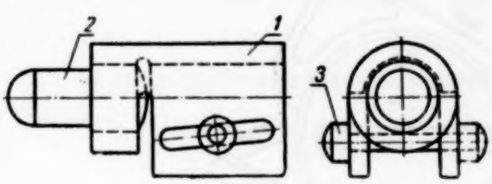


Fig. 1.

For lever gauges measuring up to 50, 75, and 100 mm a similar attachment is made with a longer rod.

The diagram of the device for checking screws in micrometers which measure over 200 mm (designed by Comr. Erekhin) is shown in Fig. 2.

The device consists of a micrometer 1 with ranges of 25-50 mm in which the fixed anvil is replaced by specially constructed grips, a fixed one 2 and a moving one 3.

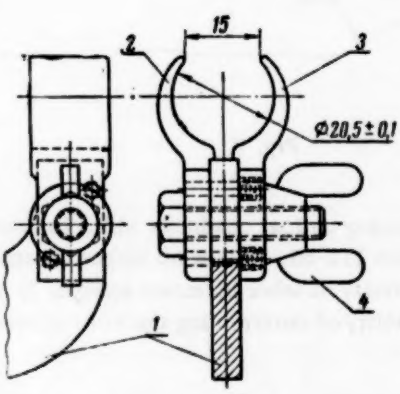


Fig. 2.

By means of wing nut 4 and these grips, the device is fixed to the frame bushing of the micrometer which is to be checked in such a manner that the screw of the checking device touches, with its spherical end, the measuring surface of the micrometer screw under test. By turning the micrometer screw of the checking device, the micrometer under test is adjusted to zero. Then the checking device is locked and the micrometer error determined by inserting end gauges.

SUMMARY

The advantages of this device consists in the self-centering of the micrometer screws and in avoiding large forces for fixing it to the micrometer under test since there are no turning efforts required in checking.

The use of this device increased the productivity of checking by 30 %.

A NEW METHOD FOR CHECKING OPTICAL QUADRANTS

G. N. Churikov

Translated from Izmeritel'naya Tekhnika, No. 4, pp 8-9, April, 1960

Checking the widely used optical quadrants must be carried out according to the method specified in instruction 112-55.

According to this method, checking is carried out on a complicated equipment which includes a standard dial with angle calibrations and an error not exceeding 10", a special microscope with a helical vernier scale calibrated to 6", a level with calibrations not exceeding 10", a base plate, centering chucks, a drive, and several auxiliary devices.

Experience has shown that the recommended equipment is complicated, insufficiently reliable for a correct determination of the error in the quadrant readings and that its productivity is very low.

Fig. 1.

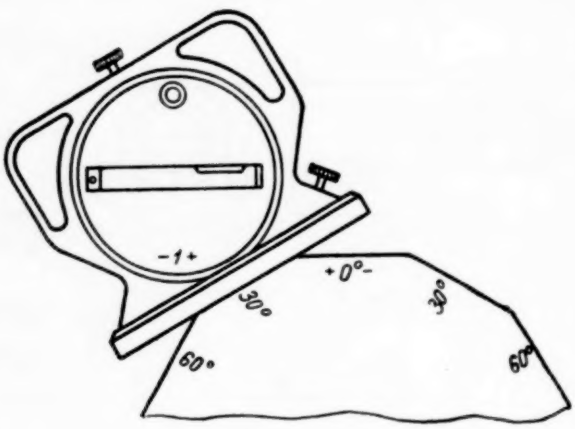


Fig. 2.

The author of this article has developed an equipment for checking optical quadrants which has considerable advantages as compared with the one recommended in instruction 112-55: 1) It is no longer necessary to use a large number of diverse devices and instruments; 2) the productivity of labor increases tenfold; 3) the accuracy of determining the quadrant errors is increased; 4) the reliability of determining the error of readings is raised.

The equipment (Fig. 1) is based on the use of a polyhedron measuring 50 × 35 mm. The equipment is mounted on a plate 1 to which is fixed a rectangular stand 2. Polyhedron 3 fixed to a step of the stand has angles whose error does not exceed ±3", although according to the specified tolerances, this error may amount to ±10". Three set screws 4 are used for levelling the instrument (one of them is not shown on the drawing).

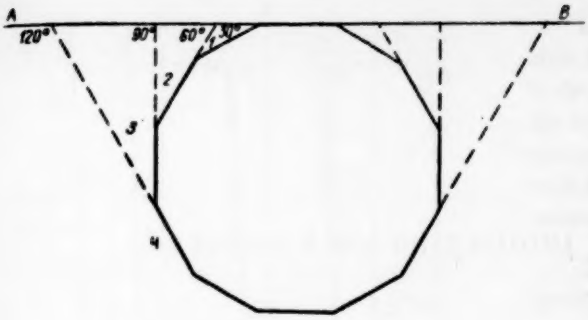


Fig. 3.

Three details 5 serve as packing (one of them is not shown on the drawing). The supporting ring serves to locate the quadrant with respect to the longitudinal axis of any of the polyhedron sides.

The technique of checking optical quadrants by means of the above instrument consists of the following: the quadrant dial is placed in the zero position and the quadrant is placed on the side marked 0° (Fig. 1); in this position the side of the quadrant's base must rest against the collar of the supporting ring. Next the bubbles in the longitudinal and the transverse levels of the quadrant are brought into their middle positions. Then the quadrant is lifted and its dial set to +30°. When the quadrant is placed on the side marked + 30° (Fig. 2) difference in the position of the longitudinal level bubble with respect to the original (middle) position is observed and, thus, the quadrant error obtained.

Consecutively, the quadrant is placed on the sides marked 60°, 90°, and 120° and the positive reading of the quadrant checked at these points. The negative readings are checked in a similar manner.

The placing of the quadrant on the sides of the polyhedron has no effect on the readings of the quadrant, since the mass of the instrument ensures its stability.

The theoretical foundation of the method is represented schematically in Fig. 3, in which the relation between the position of the polyhedron sides with respect to the horizon line AB is shown.

The internal angle of a regular polyhedron is equal to 150°. Side 1 forms with line AB an angle of 30°, side 2 an angle of 60°, side 3 an angle of 90°, and side 4 an angle of 120°.

Line AB is rigidly connected to the directions of the polyhedron sides thus avoiding the error of adjusting given angles to the lines of the horizon. Moreover, the possibility of an accumulated error is completely excluded.

The above instrument has been successfully used in the laboratory for linear and angle measurements of the VNIIK.

SUMMARY

The above equipment is simple and provides, with great productivity, accurate checking of quadrants by means of a simple procedure.

INVESTIGATING MEASUREMENT ERRORS OF INDICATING HOLE GAUGES

G. B. Kainer

Translated from Izmeritel'naya Tekhnika, No. 4, pp 9-11, April, 1960

Indicating hole gauges are the most widely used instruments for measuring internal dimensions of details. However, the effect of all the relevant factors on the total measurement error of these instruments has not yet been sufficiently studied.

We used an inductive transducer BV-908 with a recorder BV-662 for these investigations. The end of the transducer's measuring rod was made to rest against the indicator's rod and all its displacements were registered on the recorder chart. From this the reasons for the effect of surface finish and other factors on the error of measurement were established.

Repeated recordings of measurements of the same object made by various inspectors have shown that each inspector has his own characteristic "manner" of measurement. By comparing recording of measurements made by the same inspectors under different conditions, it is possible to judge,by the variation of his "manner," the effect of various factors on the measurements.

Figure 1 shows recordings of measurements made by means of an indicating hole gauge of a polished (Fig. 1a), ground (Fig. 1b), and bored (Fig. 1c) rings.

Point A denotes the beginning of measurements; the measuring tip is placed inside the hole and the inspector begins to rock the hole gauge in the horizontal and vertical planes in order to find the maximum and minimum values of the hole diameter. Point B denotes the end of the measurement; the inspector has established the size of the hole.

Knowing the scale of the recording chart and its speed of movement, it is possible to determine the deviation of the size for each rocking of the hole gauge and the durations of each measurement and rocking.

The comparison of recordings shown in Fig. 1, demonstrates the decisive effect of the surface finish on the measuring process: the rocking frequency and amplitude rise with surface roughness; large rocking amplitudes are the main source of measurement errors. These phenomena can be explained in the following manner.

When measuring ground and bored rings,the measuring tip of the hole gauge is displaced along the microirregularities of the ring surface. The measured dimension changes with variations in the pitch, height and direction of the microirregularities even with small displacements of the measuring tip. The variations in the diameter of a ground ring amounted to 1-2 μ and those of a bored ring to 3-4 μ, causing instability in the readings of the recording device. The instability of the measurements in turn causes the inspector to increase the amount and amplitude of rocking of the gauge (Fig. 1b and 1c), which provides the main source of errors in measuring ground and bored rings.

In order to decrease the effect of the surface finish on measurement, it is necessary to increase as far as possible the radius of the hole gauge measuring tip and raise the measuring effort. At the same time in specifying the measuring instruments to be used, the finish of the surface and its machining should be taken into account.

The study of measurements by means of the hole gauge showed that the error of measurements depends on the placing of the instrument in the hole (displacement and slant of the measuring line).

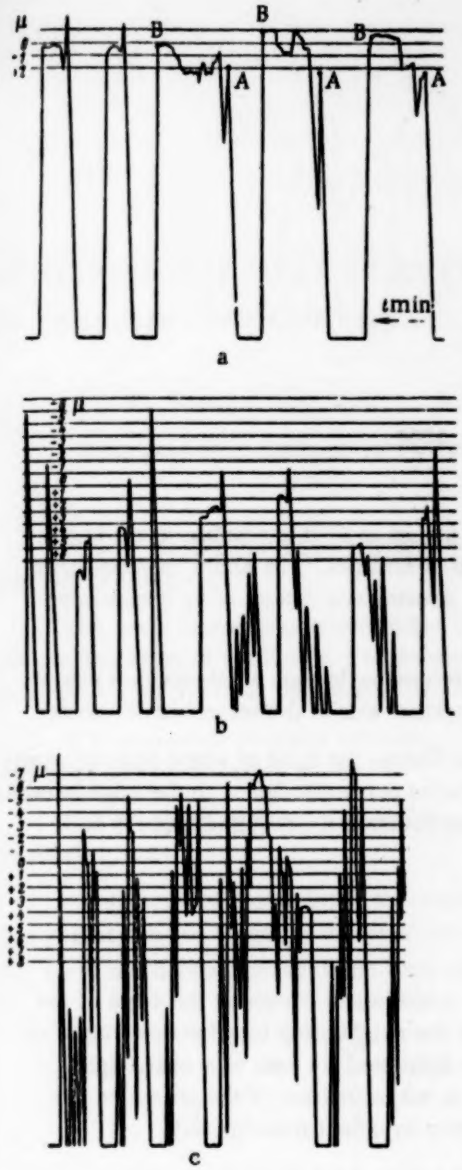


Fig. 1.

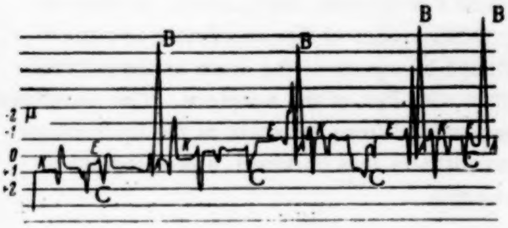


Fig. 2.

In measurements by means of the hole gauge the setting error is large because the inspector has to measure simultaneously the minimum dimension in the vertical and the maximum in the horizontal directions. Neither is it possible to differentiate between these dimensions or to arrange the measurements in such a manner that those made in one plane did not affect the measurements made in the other plane.

Differential measurements in each plane are made by means of an optimeter and a moving table mechanism. The measured ring was fixed to the optimeter table. The hole gauge was set to the size by means of the optimeter table and the reading was taken on the hole gauge dial.

Figure 2 shows the recording of such a method of measurement of a bored ring 35 mm in diameter.

Point A is the beginning of measurement in the horizontal plane. The dimension decreases sharply at first (point B), since the measuring tips are placed on a chord. Gradually the dimension increases reaching finally the maximum diameter at point E. Next, measurements are made in the vertical plane. The dimension increases sharply (point C), since the measuring tips are inclined toward the axis of the hole. Gradually the dimension decreases reaching finally its minimum in the vertical plane; this is the final dimension at the flat portion of the curve K.

The comparison of recordings of measurements made by different inspectors showed that the measuring manner of practically all the inspectors was identical, since the setting for size was made by a mechanical displacement.

SUMMARY

The use of an indicating hole gauge with 0.001 mm calibrations in conjunction with an optimeter table provides accurate measurements of 6-10 mm diameter holes which cannot be measured on an optimeter.

Comparison of recordings (Fig. 1c and Fig. 2) indicate the great effect of hand setting on the accuracy of measurement. In order to decrease the error of hand setting in the horizontal plane all the types of hole gauges should be made self-centering and for a reduced error of hand settings in the vertical plant, cylindrical instead of spherical tips should be used.

MEASUREMENT OF DIHEDRAL ANGLES BY MEANS OF A LINNIK MICROINTERFEROMETER

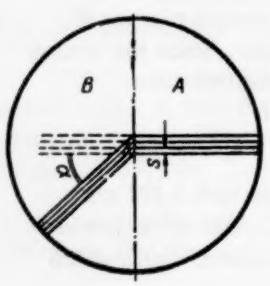
É. I. Brainin

Translated from Izmeritel'naya Tekhnika, No. 4, p. 11, April, 1960

For measuring dihedral angles close to 180° (±5°) with an accuracy up to 5' it is possible to use Linnik's microinterferometer, which is normally used for determining the finish of surfaces. The above measurement can be made in two ways: either by photographing the bending of the interference fringes or by consecutive focusing.

In both cases the detail is placed on the stage of the microinterferometer in such a manner that one of the sides of the dihedral angle is approximately perpendicular to the optical axis of the microinterferometer.

In using the photographic method the edge of the dihedral angle divides the field of vision approximately in half, and the interference fringes on one of the sides (side A) are placed perpendicular to the edge between the two sides A and B (see Figure). In this instance the required angle φ is determined from the relation



where α is the angle of inflection of the interference fringes at the edge of the dihedral angle; S is the distance between the neighboring interference fringes on side A, mm; λ is the wavelength of the light used (in case of a white light $\lambda \simeq 55 \cdot 10^{-5}$ mm); and K is the full linear magnification of the object on the photograph (as determined by photographing an object micrometer).

In the consecutive focusing method a slide drive ST-12 is fixed to the microinterferometer stage, thus providing a displacement for the detail in a direction perpendicular to the edge of the dihedral angle. The coordinate of such a horizontal displacement is measured on the vernier scale of the slide drive with an accuracy of 0.1 mm. Other values of this coordinate to either side of the edge of the dihedral angle are obtained by focusing the image by means of the drum on the micrometer drive thus making the center of the interference pattern coincide with that of the eyepiece. The coordinate of such a vertical displacement of the microinterferometer tube is determined from the scale of the micrometer drive drum with an accuracy up to 0.2 μ. From the values of both coordinates thus obtained, a profilogram of the surface is plotted from which it is easy to determine the required angle.

We obtained a good agreement between the measurements of dihedral angles produced by the two methods.

MEASURING THE WEAR OF CUTTING TOOLS IN WELL-SINKING COMBINES

A. V. Kuznetsov and L. B. Glatman

Translated from Izmeritel'naya Tekhnika, No. 4, p. 12, April, 1960

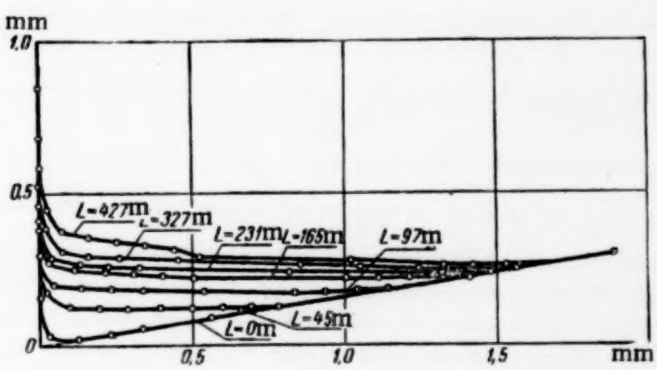
In well-sinking combines equipped with actuating elements which use cutting tools, the latter wear out as the rock is being cut.

The main factors which determine the wear of cutting tools reinforced with hard alloy plates consist of the configuration of the cutter, the abrasive properties of the rock, the length of the path traversed by the cutter in contact with the rock, the cutting parameters and the brand of the hard alloy.

It is impossible to make efficient cutting tools without knowing the relations between the wear of the tools and main factors affecting it.

Yet the study of these relationships is difficult owing to the lack of a sufficiently accurate method of measuring wear.

Techniques of determining the wear by the rear plane and the radius of curvature of the cutting edge, by the weight and the length of the path traversed by the cutter, do not provide a sufficiently accurate estimate of the basic relationship between the wear and the configuration parameters of the cutter.



In order to establish the above relationships, both under laboratory and field conditions, we developed and used a technique and devices for measuring the profile of the cutting tool during its wear.

The device for determining the profile of cutters taken from the actuating elements of well-sinking combines is based on a small measuring microscope, in which the slide is replaced in the measuring stage by a chuck for the cutter and the optical system is replaced by a holder which carries a clock-type extensometer. The extensometer axis is placed at 30° to the vertical. An ordinary pickup sapphire needle is used as its measuring tip.

In operation, the cutter which is fixed to the stage is placed under the needle and the coordinates of its profiles in various sections are obtained by manipulating the stage-adjusting screws and taking the readings of

the extensometer. For this purpose it is necessary to have a fixed datum line from which to make the measurements. The rear section of the cutter which is perpendicular to the cutter axis, and is not worn during cutting operations, serves as the datum line.

In order to avoid any possible inaccuracy due to the deviation from the perpendicular or irregularities in the surface of this section, the zero line is determined in 8-10 points and their mean is taken as the datum line with respect to which coordinates of the cutter's profile are measured. The cutter profiles obtained for various degrees of wear can be superposed,one on top of the other.

The figure shows profiles of cutter ShBM-2 used for cutting sandy shale. Similar graphs can be obtained for any vertical plane perpendicular or parallel to the cutter's leading edge.

By means of such graphs it is possible to determine very accurately both the linear and volumetric wear of the cutting tools.

The second device developed by us provides a direct measurement of the absolute wear of cutters at any point of the cutter's path in the rock on laboratory test benches,without taking the cutter out of the strain-gauge device.

The main features of this device consist of the following: a watchmaker's tool slide is bolted to clamping brackets which are tightly fixed to the test bench. An extensometer designed to operate with the slide is fixed to the bracket. The cutter's profile is measured in a similar manner to that used for the first device.

MEASURING RADIAL WOBBLE IN GEAR-WHEEL RIMS

V. N. Levitskii

Translated from Izmeritel'naya Tekhnika, No. 4, p. 13, April, 1960

We measured the radial wobble of a gear-wheel rim by means of an extensometer with a special ball tip for whose manufacture we used worn indicator tips. For this purpose we turned a spherical surface at the butt end of a tip, a surface which was first covered with a thin layer of tin solder, and then a steel ball bearing was placed in it and soldered with an acid flux and an electric iron and finally the acid was neutralized in a soda solution. The tip thus made was screwed into the measuring rod of an extensometer. The size of the ball bearing was selected according to the module of the gear wheels to be tested, so that the ball made contact in the grooves of the gear teeth at a circumference approaching the indexing size. Measurements were made in normal centers or directly under production conditions.

The gear wheel was placed on a mandrel and fixed in the centers of the lathe. The extensometer, with the ball tip selected to fit the module of the gear wheel under test, was fixed in a universal stand or by means of a special holder to a height gauge, and the extensometer ball tip was placed in the grooves along the axis of the gear wheel.

The scale was placed in the zero position. Then by turning the wheel about the axis, the extensometer tip was inserted in turn into each groove.

MEASUREMENT OF MASS

NEW REPLICAS OF A STANDARD UNIT OF MASS

N. A. Smirnova

Translated from Izmeritel'naya Tekhnika, No. 4, pp 13-14, April, 1960

Three new replicas of a standard unit of mass and new working units have been made in the Measures' Laboratory of the D. I. Mendeleev All-Union Scientific Research Institute of Metrology.

At present there exist four replicas of the same grade of standards. One of the replicas, like the main USSR standard and the international prototype of a kilogram is made of an alloy of platinum and iridium; two replicas are made of stainless steel and one of bronze. All the working standards are made of stainless steel.

In checking the working standard against the stainless steel replicas the error of comparison amounts to $^2/_3$ of that obtained in checking them against the platinum iridium replica. This is due to the effect of the aerostatic pressure when standards of different volumes are being compared.

For the same reason the error in comparing the stainless steel replicas with the main standard will be larger than that obtained in comparing it with a platinum-iridium standard. There is no doubt that the stability of the stainless steel replicas in lower than that of the platinum iridium one.

On this basis it is advisable to divide the replicas of the main standard into two categories, one of them consisting of the platinum-iridium replica $R_1 \frac{\text{PtIr}}{1\text{ kg}}$ and the other of the stainless steel replica, $B \frac{\text{st}}{1\text{ kg}}$ No. 6, and $H \frac{\text{st}}{1\text{ kg}}$ No. 8, and the bronze $\text{Gor} \frac{\text{CuSn}}{1\text{ kg}}$ No. 12.

For checking the working standards only replicas of the second category, which can be called the working replicas, will be used. This category should have at least one more stainless steel kilogram replica added to it, since the working replicas are extensively used in checking the working standards. The platinum-iridium kilogram will not be used for checking the working standards.

At first sight it would appear that in checking the replicas against the main USSR standard it is most expedient to compare all the replicas at once. However, this is not so, in view of the following peculiarities of the standards and of the method of their comparison.

The main standard is subject to wear no matter how elaborately and carefully it is used; hence it should be used as little as possible in checking the replica.

The main error in checking the replicas is that of comparison, since the error of the main standard is negligible compared with the error of weighing. As has already been pointed out, the error in comparing replicas made of stainless steel is about 1.5 times larger than the one involved in comparing the platinum iridium replica $R_1 \frac{\text{PtIr}}{1\text{ kg}}$ with the main standard. Therefore it is advisable to compare with the main standard only the platinum-iridium replica and for greater safety one of the stainless steel replicas. Next, all the replicas should be compared to each other in all the possible combinations and on the basis of these comparisons the mass of each replica determined by the method of the least squares. In the intervals between the comparisons of the replicas with the main standard (15-20 years) it is necessary to keep the working replica variations within the tolerances. This checking can be done by comparing every 5-7 years the working replicas with the $R_1 \frac{\text{PtIr}}{1\text{ kg}}$ replica. The latter replica can be used for reference purposes on very sound grounds, because it will not

be used for checking the working standards and for the 83 years of its existence it has shown a very good stability.

If in routine testing it is found that the mass of one of the working replicas exceeds its tolerance, this replica should not be used until it is checked against the main standard. In exceptional cases it is possible to ascribe to this replica a new value, by checking it against the $R_1 \frac{PtIr}{1\ kg}$ replica, and use this value until the time of routine checking against the main standard.

The calculation of possible errors shows that the root-mean-square error obtained in comparing all the replicas with the main standard is equal to 0.0043 mg whereas the same error for the $R_1 \frac{PtIr}{1\ kg}$ replica is 0.004 mg. When only two replicas are compared with the main standard the root-mean-square error for the $R_1 \frac{PtIr}{1\ kg}$ is equal to 0.004 mg; the error for the stainless steel replica, which is compared directly with the main standard, amounts to 0.005 mg and the error of the replicas which are not compared directly with the main standard amounts to 0.006 mg.

Thus in both cases the error in determining corrections for the replica standards is practically the same, despite the fact that in complete all-round comparisons the main standard is used in 200 comparisons, whereas in the proposed technique it is only used 40 times.

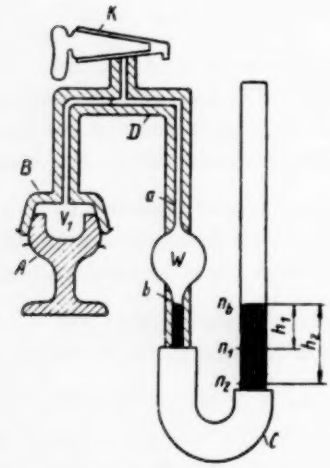
MEASUREMENTS OF VOLUME

DETERMINING THE VOLUME OF GRANULATED SUBSTANCES IN SMALL QUANTITIES

P. G. Deineka

Translated from Izmeritel'naya Tekhnika, No. 4, pp 14-16, April, 1960

In determining densities of substances it is easy enough to measure their weight with a high degree of accuracy by means of balances. It is however, much more difficult to determine the volume especially in the case of powders, granules, or small crystals. Lermontov's well-known instrument for determining the volume of such substances [1], which is widely used in school laboratories, has not been adopted in research work owing to its low accuracy. The low accuracy of the instrument is due to the fact that the relation between the volume W of the auxiliary sphere and the volume V_1 of the container, in which the substance under test is placed, is arbitrary (for instance, $V_1 = 200$ cm^3, and $W = 36$ cm^3) and therefore the difference h_2-h_1 of the manometer mercury levels corresponding to a filled and empty container is small, and variations of this distance provide the main source of errors. However, difference h_2-h_1 can be considerably increased if the correct ratio between V_1, W, and the volume V of the substance under test is correctly chosen. Moreover, the volume of the container in which the body under test is placed is too large (of the order of 200 cm^3) and the volume of the substance under test must therefore be also large, for instance, 100 cm^3. Measurements of smaller volumes lead to even greater errors. Thus in measuring volumes of the order of 10 cm^3 the error amounts to 20% whereas it is often required in experimental investigations to measure considerably smaller volumes when only small quantities of the required substance are available.



We made it our objective to use Lermontov's method for determining with greater accuracy small volumes of the order of 0.5 cm^3, i.e., volumes $^1/_{200}$ of the normally measured size.

The instrument* consists of a wine-glass shaped vessel A (see figure), on to which lid B is fitted with vacuum cement and secured by a rubber loop with special extensions. Container A is connected to the mercury manometer C by means of a capillary tube D 0.2 mm in diameter. Tube D ends in a swelling in the shape of sphere of volume $W = 0.7$ cm^3. Below the sphere the tube internal diameter is considerably larger (amounting to 2.5 mm) in order to prevent the mercury from separating during its rise and fall and admitting air. Vacuum tap K serves to connect container A with the surrounding atmosphere.

At the beginning of the experiment tap K is opened and the mercury level is fixed at mark a in the left-hand column of manometer by adjusting the height of its right-hand column. The air volume in the container and the tube up to mark a is denoted by V_1. In our instrument $V_1 = 1$ cm^3. Next, tap K is closed and the contained mass of air is increased in volume to the level to mark b by lowering the right-hand column. Now the volume of air will amount to $V_1 + W$, and the internal pressure will be below atmospheric pressure H by the amount of $h_1 = n_b - n_1$. It follows from Boyle's law that

$$V_1H = (V_1 + W)\ (H - h_1),$$

*V. B. Orlovskii, a student of the LTI, took part in the making of the instrument and carrying out of the experiments.

whence

$$V_1 = \frac{W(H-h_1)}{h_1}; \quad h_1 = \frac{WH}{V_1+W}. \tag{1}$$

Next the lid is taken off container A and the substance whose volume V it is required to measure is placed in the container, the lid replaced and the mercury level in the left-hand column set at mark a by adjusting the right-hand column with tap K open, and then,having closed the tap, the volume of air is extended to mark b when it becomes equal to $V_2 = V_1 - V$. Now the internal pressure will be below the atmospheric pressure H by the amount $h_2 = n_b - n_2$ and $h_2 > h_1$.

Thus

$$V_2 = \frac{W(H-h_2)}{h_2}; \quad h_2 = \frac{WH}{V_2+W} = \frac{WH}{V_1-V+W}. \tag{2}$$

The required volume is equal to

$$V = V_1 - V_2 = \frac{WH(h_2-h_1)}{h_1 h_2}. \tag{3}$$

This volume can also be obtained by compressing instead of rarefying the air inside the container and the tube from mark b to mark a by lifting the right-hand column of the manometer.

In order to raise the accuracy of the instrument it is necessary to choose a relationship between quantities V_1, W, and V for which the differences h_2-h_1 in (3) is at a maximum. According to (1) and (2) the relation between h_2-h_1, and V_1, W, and V is expressed by the following folmula:

$$h_2 - h_1 = \frac{WH}{V_1-V+W} - \frac{WH}{V_1+W} = \tag{4}$$

$$= \frac{WVH}{(V_1+W)(V_1-V+W)}.$$

By equating the first derivative $\frac{d(h_2-h_1)}{dW}$ to zero we obtain

$$\frac{d(h_2-h_1)}{dW} = \frac{VH(V_1^2 - V_1V - W^2)}{[(V_1+W)(V_1-V+W)]^2},$$

whence,

$$V_1^2 - V_1V - W = 0$$

or

$$W = \sqrt{V_1(V_1-V)}.$$

Having ascertained that the second derivative $\frac{d^2(h_2-h_1)}{dW^2}$ is negative for $W = \sqrt{V_1(V_1-V)}$ we arrive at the conclusion that the difference h_2-h_1 is at a maximum when

$$W = \sqrt{V_1(V_1-V)}. \tag{5}$$

Let us now examine a few possible cases.

1. Let the substance occupy almost the whole of vessel V_1, for instance $V = 0.99\ V_1$. Then according to (5) the volume of the sphere $W = \sqrt{(V_1)(V_1 - 0.99V_1)} = 0.1\ V_1$.

2. If the volume of the substance is very small, for instance, $V = 0.01V_1$ then $W = V_1$.

Let us now calculate the difference h_2-h_1 for these two cases from (4). In the first case when V = 0.99 cm^3 and W = 0.1 cm^3 (with V_1 = 1 cm^3) we have

$$h_2-h_1=\frac{WVH}{(V_1+W)\,(V_1-V+W)}=\frac{0.99\cdot 0.1\cdot 76}{(1+0.1)(1-0.99+0.1)}=62\text{cm}$$

In the second case when V = 0.5 cm^3 and W = 0.7 cm^3 we obtain h_2-h_1 = 13 cm. In the third case when V = 0.01 cm^3 and W = 1 cm^3, we find that h_2-h_1 = 0.19 cm.

It will be seen that the largest difference and,hence,the greatest accuracy is obtained when the volume V_1 is completely filled with the substance. Since, however, it is impossible to achieve this in practice, as volume V_1 includes not only the internal cavity of the wine glass, but also all the space above it and the capillary tube up to tap K and mark a, which cannot be filled with the substance, we adopted in constructing the instrument the second alternative in which the substance under test occupies approximately half the volume V_1 consisting of the wine-glass capacity of about 0.5 cm^3.

Since in this instance the difference h_2-h_1 = h amounts to 130 mm and the absolute error Δh of this difference amounts to no more than 1-1.5 mm on the millimeter scale the relative error $\Delta h/h$ will be smaller than 1.5%. The total of the relative errors of the remaining quantities (h_1, h_2, H, and W) comprising (3) and required for calculating the volume will amount to less than 1%, since for the same reading accuracy these quantities are larger than the values of h_1 and h_2 calculated from (1) and (2) and are respectively equal to 313 and 433 mm and H = 760 mm, whereas the error in volume W, determined in advance by weighing the mercury which fills it, is negligible. Hence the total error in measuring a volume of the order of 0.5 cm^3 will amount to some 2%.

The operation of the instrument was checked in the following manner. The density of a glass cylindrical rod was determined from its weight and dimensions, another portion of the same rod was ground into small pieces and powder whose density was determined by means of the above instrument. The results of these measurements are given in the Table below.

Sample	n_b	n_b mean	n_1	n_1 mean	n_2	n_2 mean	$h_1 = n_b - n_1$	$h_2 = n_b - n_2$	Volume V, cm^3	Mass m, g	$\rho = \frac{m}{V}$
Broken glass	44.9	44.84	15.0	14.94	8.6	8.58	29.9	36.26	0.31	0.786	2.53
	44.8		14.9		8.6						
	44.9		14.9		8.5						
	44.8		14.9		8.6						
	44.8		15.0		8.6						
Glass rod	–	—	–	–	–	–	–	–	2.52	6.315	2.51

A good aggrement between the two methods of measurement will be seen from the table. It is also easily seen that the error of determining a volume of 0.31 cm^3 of broken glass does not exceed 2%. The table. also shows a good consistency in the numbers of n_b, n_1, and n_2 read off the millimeter scale of the manometer. The accuracy of the instrument can be greatly raised if in its manufacture the "deadspace " over the wine-glass container is decreased, by the skillful work of the glass-blower and grinder.

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MECHANICAL MEASUREMENTS

HIGHLY PRODUCTIVE HARDNESS GAUGES ARE REQUIRED

B. N. Vorontsov

Translated from Izmeritel'naya Tekhnika, No. 4, pp 17-19, April, 1960

It is difficult to overestimate the importance of instruments for determining the hardness of metals normally used in the engineering industry. Yet there are only two types of these instruments: the TSh and the TK, despite the variety of requirements with respect to their working properties presented by large-and small-scale mass-production plants and establishments with individually produced commodities.

The hardness gauges TSh and TK, which have been produced by our industry for more than 25 years, have hardly changed in design and their productivity remains the same as 25 years ago, although the scale, manner, and rate of production in our plants has increased enormously during that time.

The attached table shows the distribution of hardness-measuring instruments in our industry.

Basic purpose of instruments	Type of instrument commercially produced		Sphere of instrument's application
Laboratory-type instruments	TSh-2	TK-2	Laboratories and small-scale mass-production plants
High-speed instruments for checking components	None	None	Large mass-production plants
Instruments for automatic checking of hardness	"	"	Mass-production conveyor-belt plants
Instruments for checking large components	"	"	Heavy-engineering plants
Portable instruments	"	"	Determining the hardness of constructional details and large products
Instruments attachments to them for checking internal surfaces	"	"	Laboratories or plants
Instruments for determining the hardness of surface layers	"	"	The same

It will be seen from the table that the requirements for testing the hardness of metals are not met by the laboratory type instruments TSh-2 and TK-2 which are produced by our instrument-making plants. The lack of high speed and automatic instruments for checking hardness in large mass-production conveyer-belt plants is particularly disturbing.

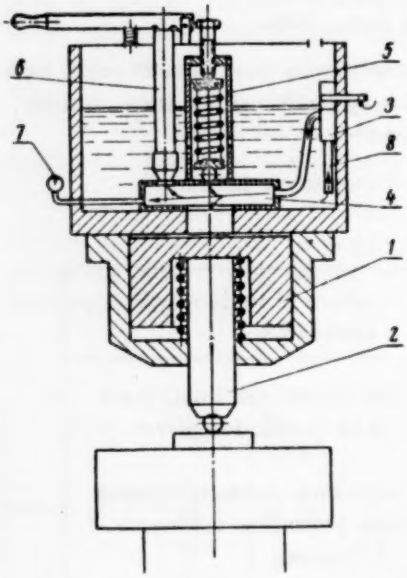
In referring to the metrological properties of the TSh-2 hardness gauges one should mention their stability and precision. Their productivity, however, is extremely low and they are inconvenient to use under production

conditions. The TSh hardness gauges completely meet the requirements of laboratory type instruments. For work under mass-production conditions new and more productive instruments should be immediately developed by our instrument making plants. The lack of such instruments forces engineering plants to make, by the means at their disposal, hardness gauges which are better in operation than the TSh type instruments.

When the Gor'kii Automobile Factory began operations, there were found in use many instruments of the Brinell type, whose construction guaranteed high productivity and, at the same time ensured the quality control of the hardness of machined details. Also, at the Ul'yanov Automobile Factory, similar instruments made by the factory itself were used, superior in operation to the TSh hardness meters.

The Gor'kii State Laboratory of Measurement Equipment investigated in 1959, in a number of plants, the condition of the available instruments for measuring hardness and their suitability for the production techniques employed. The results of the investigations, which showed a pronounced lagging of the hardness control methods, utilizing the existing instruments, in regard to the requirements of conveyer-belt mass-production, were discussed with the representatives of the plants concerned.

The conference decided to make at one of the Gor'kii factories, from a drawing supplied by the Ul'yanov Automobile Plant some 5-10 new instruments which are more productive than the TSh hardness gauges, and with these replace the obsolete low production hardness gauges which do not meet modern production requirements.



The new instruments will be introduced in the plants of the Gor'kii Council of National Economy in 1960.

The schematic of the hardness-gauge hydraulic-pressure device is shown in the figure. The lower part of the chamber contains piston 1 with spindle 2 and a spring, which serves to return the piston to its original position after testing. The upper part of the chamber contains the principal devices which produce and control the loading of the piston: a gear-driven oil pump 3 connected by means of a pipe with the inner pressure chamber 4, a control valve 5, and an output valve 6. The internal chamber 4 is connected by a pipe with manometer 7.

The upper chamber is filled with oil, through the hole in its lid, up to the level of the pump-motor pulley. Oil pump 3 drives the oil from the intake pipe 8 to pressure chamber 4. If outlet valve 6 is closed by means of the handle, the oil pressure in chamber 4 rises and is transmitted to piston 1 and spindle 2 and, hence, to the component under test. Control valve 5 serves to set the pressure at the required value, which is achieved by adjusting the tension of the valve spring by means of the set screw. As soon as the pressure in chamber 4 attains the set value, the control valve opens and the surplus oil flows out into the main chamber through the control-valve hole. Thus, despite the continuous flow of oil, supplied by the pump, the pressure required for testing is maintained in chamber 4 as long as the outlet valve 6 is closed.

When outlet valve 6 is released the pressure is taken off the piston and it returns to the normal position by means of its spring. The lever of valve 6 can be made either hand- or foot-operated, according to the requirements.

The high productivity of the instrument is achieved by means of its following operational properties: the working pressure on piston 1 and, hence, on the ball of spindle 2, is attained in 1-2 sec; the spindle has a stroke of 20-25 mm, thus providing the testing of similar details without lifting or lowering the table for each detail; since the instrument has two control valves 5, it is easy to pass from one load to another, for instance from 3000 to 750 kg-wt, by simply switching the valves without any loss of time.

In addition to the above advantages of this instrument as compared with the TSh hardness gauge one should also note the considerably easier operation of the instrument which saves the inspector the labor of turning the lifting screw wheel after each tested detail.

A reader not acquainted with the operation of instruments of this type may well doubt the accuracy of the instrument readings, since this hardness testing could fail to meet the GOST requirements with respect to the duration of the pressure on the sample, a duration which depends on the time the inspector presses on the valve 6 lever.

Normally the lever is released as soon as the pointer of the manometer mounted on the front of the instrument, attains its maximum set reading, which takes about 3-4 sec. Thus, the instrument does not provide a strictly defined duration of pressure on the sample and the accuracy of the readings appears to be doubtful.

Numerous tests carried out at the Gor'kii Automobile Plant with samples made of different materials have shown, however, that the error of measurements due to the duration of pressure on the samples under test is practically negligible under production conditions, since the method of measuring the indentation by means of a magnifying glass (or microscope with a magnification of 20), a scale graduated in 0.1 mm, and a rough finish of the surface used for obtaining the indentation, produce a much larger error than the one due to the duration of the pressure on the sample.

The stability of the control valves 5 is such that they can provide with easy adjustment an accuracy of ±0.5%.

The defects of the instrument include in the first place its sensitivity to ambient temperature variations.

Large temperature variations in hot workshops between night and day affect the viscosity of the oil in the instrument and thus change the working load. This defect can be easily eliminated by an adjustment of the control-valve spring. In order to provide a check of the accuracy of the instrument at any time the inspector is supplied with a sample bar (hardness standard), calibrated on a reference instrument in terms of the indentation diameter.

The technique of determining the hardness of metals by Rockwell's method is also inadequate. Hardness gauges TK-2 made by our instrument-making plants cannot be used for determining the hardness of details after various kinds of thermal treatment. For instance, details with a hard surface layer (case-hardened, cyanized, etc.) cannot be tested on the C hardness scale, since the depth of indentation by the diamond cone is too great for the thin surface layers and the readings of the instrument are distorted. Some of the plants are forced, therefore, to make their own instruments for such test, by adapting either normal TK instruments or durometers. There are no instruments for measuring hardness on internal surfaces.

It would be a good idea to supply with each TK-2 hardness gauge, a special attachment consisting of a bracket for checking internal surfaces. Such a bracket cannot provide the checking of details of all diameters and configurations, but will serve as a sample from which the plants can make their own measuring attachments. Bracket attachments to the TK hardness gauges for measuring internal surfaces are used in many plants including the Gor'kii Automobile Factory.

A considerable part of the responsibility for the hardness gauges TSh and TK not meeting the production requirements must be borne by the metrological institutes, which are mainly interested in the metrological properties when testing instruments and pay little attention to their operational characteristics. In our opinion the final approval of a new instrument, intended for use in production, must only be issued after the instrument has been tested under production conditions with maximum utilization during the whole of the testing time.

The most experienced and qualified workers in departmental inspection and State Inspection Laboratories of Measuring Equipment should take part in supervising these tests.

Editorial Note. B. N. Vorontsov notes in his article the unsatisfactory providing of our industry with hardness-testing instruments.

For the 25 years since the TSh and TK instruments were first mass-produced their design has remained practically unchanged.

The lack of high speed and automatic instruments for measuring hardness is especially noticeable in large scale mass-production conveyer-belt industries.

The discrepancy between their modern automation equipment and the quality of the instruments used for measuring hardness is most pronounced in these establishments. The committee for engineering automation attached to the USSR Council of Ministers and the planning agencies should take urgent steps to eliminate this state of affairs.

NEW RETAINING AND DOG-DRIVE MECHANISMS FOR MEASURING INSTRUMENTS

K. I. Perchikhin

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In loaded-piston measuring devices one of the elements of a piston pair is provided with a rotating movement in order to obtain purely liquid friction between the piston and the cylinder walls. A free (inert) rotation of the piston in manometric instruments with a single piston pair is widely used.

It is impossible to use free rotation in complex measuring systems, and it is therefore necessary, to apply a force rotary movement to one of the elements of a pair. The transmission of this movement involves a contact between the measuring piston and a dog-drive or retaining mechanism thus increasing the measurement error.

For this purpose kinematic coupling is normally used which is attained by means of a flat stop or a retaining stay.

A compact retaining mechanism, applicable to instruments of various types, can be constructed in the form of a rotating cylinder whose axis is parallel to that of the measuring piston. In this design the well-known principle of the transfer of the friction force from one member of the mechanism to another is used.

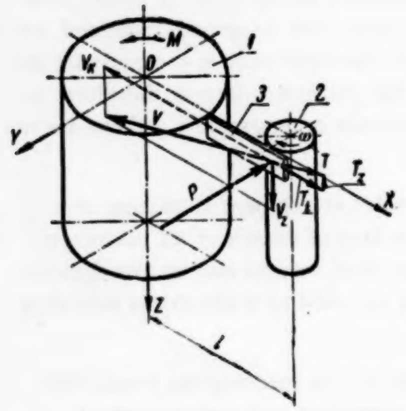

Fig. 1.

Figure 1 shows a schematic of the distribution of efforts and velocities. The moment received by the measuring piston 1 is transformed into force P, which sets up a reaction in roller 2 preventing the rotation of the piston. As the result of the contact between the piston stop 3 and roller 2 a friction force arises equal to

$$T=kP, \tag{1}$$

where K is the coefficient of friction.

The relative movement of elements 2 and 3 consists of the rotation of roller 2 with a uniform peripheral velocity V_k and the displacement of stop 3 together with cylinder 1 parallel to the Z axis with a velocity V_z. The direction of the relative movement coincides with that of the instantaneous velocity at the point of contact and can be easily determined from equation:

$$\overline{V}=\overline{V}_k+\overline{V}_z. \tag{2}$$

Assuming that the cylinder and the roller are strictly parallel, we obtain from Fig. 1 the axial component of the friction force equal to

$$T_z=T\frac{V_z}{V_k}. \tag{3}$$

The axial velocity V_z is determined in the balanced state by the lowering of the piston due to the leakage of the working liquid or to its oscillatory movement.

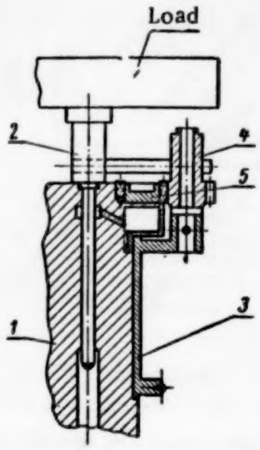

Fig. 2.

With an appropriate selection of the roller's peripheral velocity the vertical compoment of friction T_z can be made negligibly small.

The error due to the relative slanting of the two axes can also be easily eliminated.

The above design of a retaining mechanism was first used in a reference loaded-piston scales type OGV-1 of 1000 kg capacity. Tests have shown that the mechanism did not introduce any noticeable additional errors.

A similar device can be used for rotating the measuring piston. The schematic of a dog-drive mechanism with a roller which rotates about its axis is shown in Fig. 2. The stationary cylinder 1 carries a hub 3 and gear wheel 5 rigidly fixed to the cylinder. Hub 3 carries an axle with a roller 4 which is geared by means of a pinion to gear 5. Roller 4 transmits the movement to piston 2 through the dog attached to the piston, rotating it at the same angular velocity as the hub. In this movement the pinion of roller 4 runs round gear 5 and turns about its own axis with a velocity which depends on the ratio of teeth in gear 5 and pinion 4.

As the result of the rotation of the roller about its own axis the direction of the friction force between it and the dog-drive piston 2 is changed in a manner similar to the one described for the first design.

An analysis of the above device has shown that its use with the existing sizes of piston manometers does not introduce an additional error exceeding 0.001%.

A manometric instrument with forced rotation of the piston was first made to the above design for an experimental dynamometer equipment operating with a viscous liquid.

Tests on the operation of the rotating mechanism provided very satisfactory results.

A UNIVERSAL STRAIN-GAUGE EQUIPMENT UTS1-VT-12

N. N. Skvortsov

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The multichannel strain-gauge equipment UTS1-VT is designed to measure parameters and record dynamic processes by means of resistance-wire gauges and special strain, capacity or magnetic transducers.

The UTS1-VT-12 set is a twelve channel equipment working with a 35 kc carrier and registering in a range of 0 to 7000 cps.

The large power output and smooth control of sensitivity provide the possibility of working this equipment with vibration oscillographs of any types using vibrators I, II, IV, or V.

The design of the equipment covers a wide range of conditions and special requirements for mass measurements of voltages and other dynamic processes encountered in testing machines and constructions, thus making it possible to use the UTS1-VT-12 set for field, factory, and laboratory investigation of the most diverse objects.

Figure 1 shows schematically the general appearance of the equipment which consists of a 12 channel strain-gauge set UTS1-12/35 (1), a power pack V-12 (2) and connecting lines.

The strain-gauge set works on the principle of amplitude modulation of the measuring-bridges carrier voltage by the signal of the transducer, which is itself the working arm of the bridge.

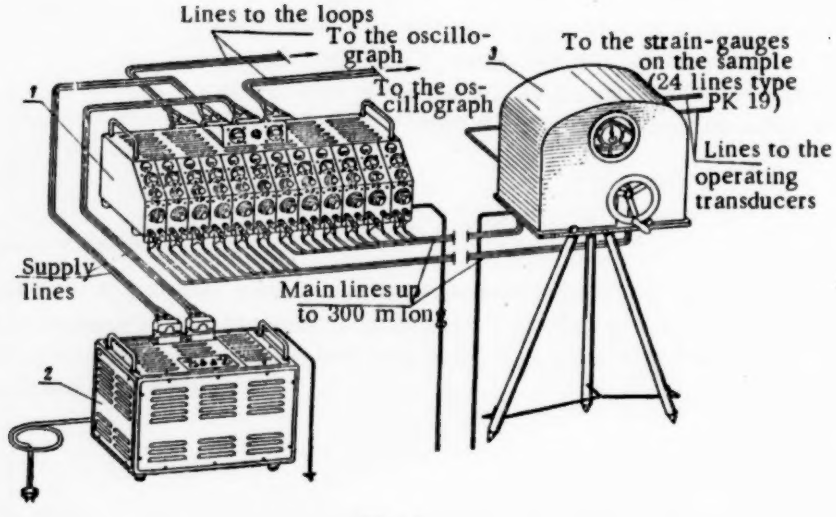

Fig. 1.

It will be seen from the block schematic that in the strain-gauge set, with its phase-sensitive demodulator (Fig. 2), the measuring bridge and demodulator are fed from a generator which supplies a voltage of a given frequency.

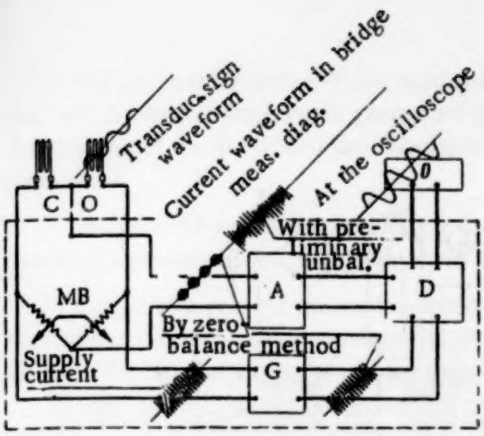

Fig. 2. C) Compensating transducer; O) operating transducer; MB) measuring bridge; A) amplifier; G) generator; D) demodulator; Osc) oscilloscope.

The detached arms of the bridge consist of two electrically similar transducers, one of them serving for measurement and the other for compensation.

The electrical symmetry of the detached arms requires internal bridge ratio-arms of equal resistance.

The advantage of systems with two detached symmetrical arms consists in placing under normal strain-measurement conditions, the compensating transducers over the elastic element of the calibrating device, thus making it possible at any instant during testing to calibrate the channels without disconnecting the operating transducers.

The variations with time of the resistance (capacity, inductance) of the operating transducers change the amplitude of the carrier frequency current which is flowing in the operating arm and the measuring diagonal of the bridge. The shape of the carrier voltage amplitude reproduces the form of the transducer signal (Fig. 2).

The voltage obtained in the measuring diagonal of the bridge is amplified and fed to the demodulator whi which separates the signal of the transducer and feeds it to the loop oscillograph.

The frequency characteristics of this type of equipment does not exhibit in the range of 0-30 cps a slope which is normal to ac amplifiers.

Its characteristic is practically linear in the range from zero frequency to a frequency 10-12% below the carrier. This makes it possible to use static calibrations and measure static phenomena.

The use of push-pull demodulators provides without distortion twice as wide a frequency band as with single-ended demodulation.

The doubling of the amplitude range in recording processes with opposite signs is achieved by using phase-sensitive demodulators (for instance ring demodulators), which provide center-zero operation with positive and negative values.

The twelve-channel strain-measuring set UTS1-12/35 has a common oscillator and 12 channels designed on the basis of the same schematic circuit. The schematic of a channel and the oscillator is shown in Fig. 3.

The oscillator consists of two stages. The driving stage is self-oscillating with 35 kc tuned circuit (T. C.) in the anode of a double triode 6N1P (T_1). The voltage from the tuned circuit (T. C.) is fed in antiphase to the grids of the buffer stage. The buffer stage consists of two 6P1P tubes (T_2 and T_3) connected in push-pull, with an output transformer Tr 1, whose secondary winding is connected to the input (measuring) bridges (B-1) of the channels and supplies the reference (phasing) voltage to the demodulator (B-2).

This circuit provides a perfect zero balance for which there is no current in the measuring diagonal of the input bridge (B -1), and gives a symmetrical (with respect to the zero point) amplitude characteristic for positive and negative unbalances.

The strain-measuring channel sensitivity is adjusted by altering the supply voltages amplitude at the measuring bridge by means of the variable resistor R_{22} (Fig. 3), which is connected to the secondary winding of Tr 2. The control knob of the variable resistor R_{22} is mounted on the front panel of the set. The linearity of the amplitude characteristic holds in the limits of ±120 ma in any position of the sensitivity-control knob.

For checking the sensitivity of the set during measurements two control resistances (R_{22} and R_{24}) are switched in parallel with the compensating arm of the bridge at the main ground terminals of the set.

The main characteristics of set UTS1-12/35 are: 12 simultaneously measurable processes; undistorted frequency range 0-700 cps; maximum linear output current of 120 ma into a three ohm load, with a continuous gain control; deviation from a linear channel amplitude characteristic ±2%; deviation from a linear channel frequency characteristic ±3%; variation in the channel gain at constant ambient temperature after 6 hours of

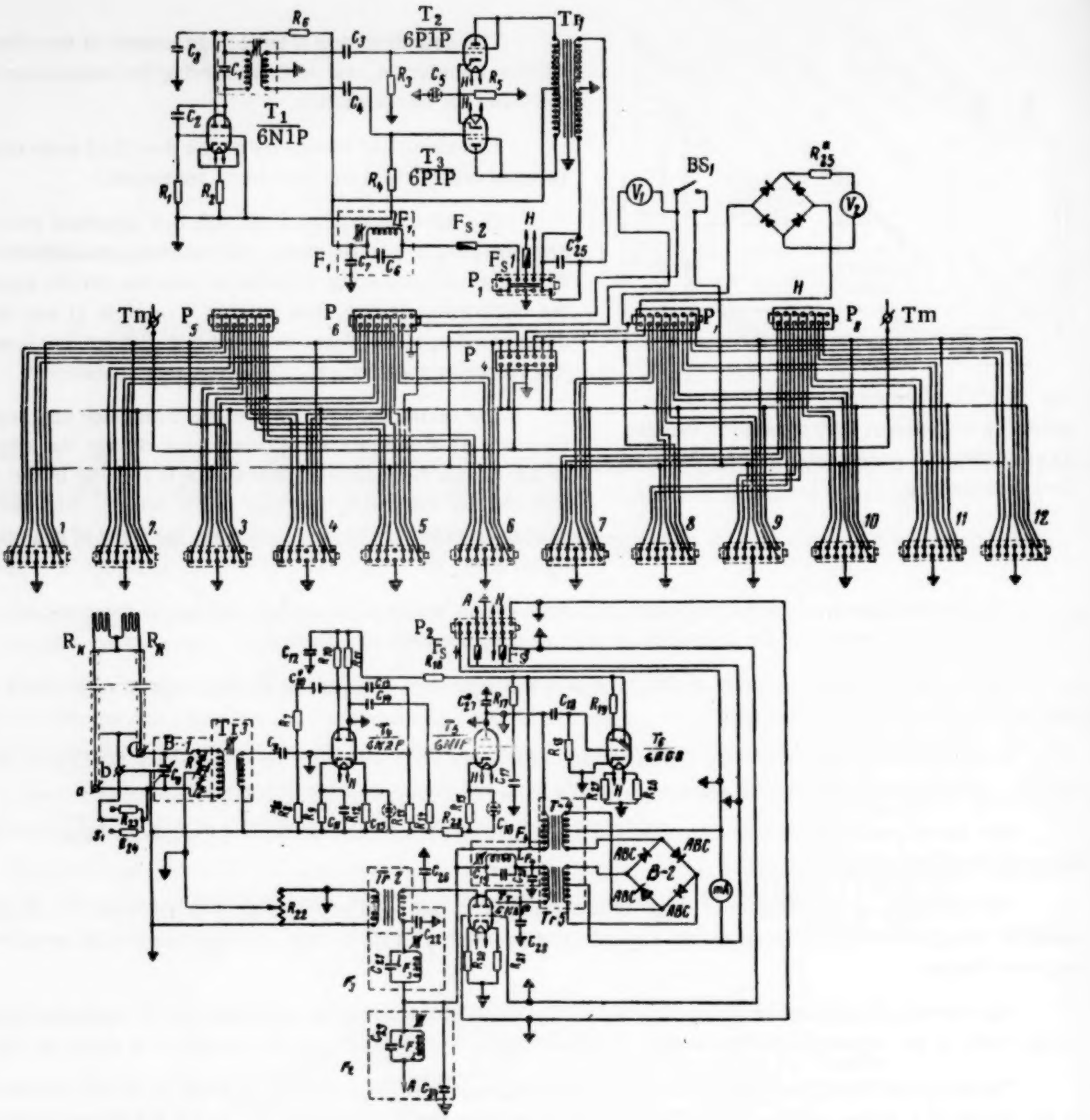

Fig. 3.

operation, not exceeding ±3%; heating-up time of the set before operation amounts to 1 hour; zero drift of balanced channels, after the set has been heated up, not exceeding 2 ma per hour of operation; the length of lines connecting the set with the operating transducers from 5 to 300 m; resistance of the symmetrical detached arms of the bridge (wire transducers) from 100 to 400 ohms; compensation for the possible resistance asymmetry of the detached bridge arms (by means of manual resistance balancing) amounts to ±1 ohm; compensation for the possible reactive assymmetry of arms (by means of manual capacitative balancing) not less than ±1200 μμf; the set is supplied from 220 v 50 cps mains; its consumption is 300 va; in over-all dimensions it is 720 mm long, 375 mm wide, and 280 mm high; its weight is 44 kg.

A power pack type V-12 is supplied with the set and provides: a stabilized ac heater voltage of 6.3 v; a stabilized dc anode voltage of 250 v for the channel and generator tubes.

The basic components of the power pack consist of a ferroresonating transformed stabilizer, a DGTs-24 germanium diode rectifier, filters and an electronic stabilizer comprising tubes 6N5S and 6N2P and a stabilivolt type SG1P.

The calibrating device T-12, supplied with the set, is based on the principle of pure bending of a beam over which compensating strain gauges are glued. By means of this calibrating device the relation between deformation of the detail and the deflection of the measuring instrument or the loop of the oscilloscope is established.

Device T-12 is used for calibrating and adjusting the strain-measuring set and for determining, in conjunction with a precision Thomson-Wheatstone bridge, the strain sensitivity of the resistance-wire transducers.

The various parts of the strain-measuring set are connected by means of three different types of lines. Main lines connect the strain-measuring set with the calibrating device. They consist of a coaxial cable type RK-19. The lines of each channel consist of lengths of the RK-19 cable.

The length of the main line, depending on the operating conditions, may vary between 5 and 300 m. Changes in the length of lines do not require variations in the adjustment of the set.

The supply lines connect the power pack to the set and consist of 14 (0.5 mm^2) conductor cables soldered to plugs. The cable is 4 m long.

The supply line plugs are numbered 2 and 3 and should be connected to the correspondingly numbered sockets. The loop lines consist of two similar 12 (0.35 mm^2) conductor cables. Their length is 1.6 m.

THE PROBLEM OF COMPENSATING THE VARIATIONS OF RESISTANCE WITH TEMPERATURE IN GLUED-ON STRAIN TRANSDUCERS

N. G. Tisenko

Translated from Izmeritel'naya Tekhnika, No. 4, pp 23-25

In order to reduce the temperature errors of strain-gauge measurements of tensions, deformations, efforts and other quantities, partly temperature-compensated strain transducers are used, whose windings contain additional wire. The temperature resistance coefficient of this wire is larger than that of the remaining winding and is positive. Thus the main winding of strain transducers may be made of hard constantan and the additional wire of copper or nichrome [1, 2, 3]. Such strain transducers can be fed with small currents only, at which the winding does not heat up. The essential defect of above strain transducers consists in their more complicated manufacture than that of transducers made of a single type of wire. The Central Aerohydrodynamic Institute developed thermocompensated type 1-P dynamometer strain transducers made of annealed constantan wire [4].

The general theory of the thermocompensated strain transducers is outlined in [1]. The wire in the sensitive winding of the thermocompensated transducers must satisfy the condition

$$\beta_0=(\alpha_0-\alpha_1)K, \tag{1}$$

where β_0 is the temperature resistance coefficient of the wire; α_0 the linear expansion coefficient, of the wire, α_1 the linear expansion coefficient of the frame, K the coefficient of the transducer's strain sensitivity.

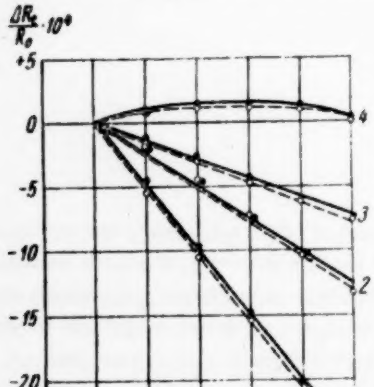

Fig. 1. —) Strain transducer; ---) wire.

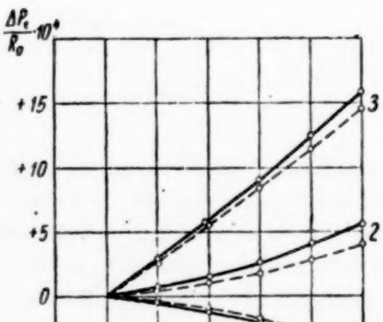

Fig. 2. —) Strain transducer; ---) wire.

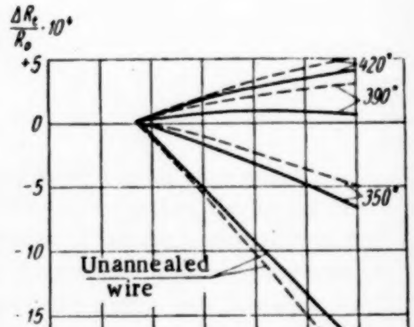

Fig. 3. —) Strain transducer; ---) wire.

In selecting the wire it is necessary to know accurately the value of α_0. It is difficult to determine the value of α_0 directly from 0.02-0.05 mm wire samples. Normally for calculation purposes, values of α_0 measured

on standard alloy samples are taken. Thus for constantan wire α_0 is chosen in the range of (14-17) · 10^{-6}.

It is possible to calculate α_0 of the winding of a glued-on strain transducer by means of the equation

$$\beta_t = (\alpha_1 - \alpha_0) K + \beta_0. \tag{2}$$

where β_t is the total temperature coefficient of a strain transducer, glued to a frame whose linear temperature coefficient α_1 is known.

The values of β_t and β_0 are determined by the usual experimental methods from the temperature characteristics of the glued-on transducers and wire samples. This technique is described in [2, 4].

From (2) the linear expansion coefficient of the glued-on transducer wire is equal to

$$\alpha_0 = \alpha_1 - \frac{\beta_t - \beta_0}{K}. \tag{3}$$

We have investigated experimentally the properties and temperature coefficients of resistance of three types of hard constantan strain-gauge wire, of nickel-chrome wire ÉI-292 (OKh25Yu$_5$) according to GOST 5632-51 in its hard and annealed states, and of strain gauges glued-on to carbon seel for which the linear expansion coefficient was $\alpha_1 \simeq 12 \cdot 10^{-6}$.

The properties of hard constantan wire (as delivered) are given in Table 1.

TABLE 1

Wire material	Diameter, mm		Resistance of 1 runningmeter, R_1 ohms/m	Resistivity ρ, ohms · mm²/m	Breaking load P, kg-wt · 10^{-3}	Tensile strength σ, kg-wt/mm²
	nominal	including insulation				
DriverCompany's hard uninsulated constantan	0.030	–	743	0.525	71	100
Driver Company's "cupron" enameled constantan	0.0255	0.032	886	0.455	38	74
Hard constantan MNTs 40-1.5 uninsulated, consignment 65 of the nonferrous metal plant OTsM	0.030	–	600	0.424	85	120

Figure 1 shows the temperature characteristic $\Delta R_t/R_0 = f(t)$ of the wires under investigation and of strain-gauges made of this wire and glued with nitrocellulose glue (curves 1, 2, 3). One of the types of wire used, was the Driver Company's "cupron" constantan wire, and the same wire in an annealed state (annealed in air at 400-450°C) its characteristic is shown by curve 4 in Fig. 1 and curve 1 in Fig. 2. Strain gauges made from this wire were glued both with nitrocellulose glue (curves 4 in Fig. 1) and with glue BF-2, subsequently polymerized (curves 1 in Fig. 2).

Figure 2 shows the temperature characteristics of ÉI-292 nickel-chrome wire samples in their hard state (curves 2) and after annealing in air at 800°C for 2 hours (curves 3), and also of strain gauges made of this wire and glued with nitrocellulose glue.

The tested strain gauges made of these types of wire all had the same dimensions (base of 10 mm, 8 turns, winding pitch of 0.2 mm), but different initial resistances, and were glued to steel samples of 4 × 7 × 20 mm. The sensitivity coefficient of the constantan wire strain gauges was K ≃ 1.9 and that of nickel-chrome gauges was K ≃ 2.70.

The heating of the wire and glued-on strain gauges was made in a water thermostat TS-15M of the "Respirator" plant in the range of ±5 to ±65°C during 2 hours. The resistance was measured on a bridge with a sensitivity of 0.001 ohm or by means of an electronic strain measuring device and the temperature on a laboratory mercury in glass thermometer (tolerance of 0.2°C). The samples were placed in the middle portion of the thermostat in thin-walled test tubes and were isolated from the water. The samples used for measuring the temperature characteristic of reel wire were prepared with special care: the wire was placed freely (without stress) along a helical protrusion on a glass tube 7 mm in diameter. Each type of wire was tested on 5 samples in 5 strain gauges.

In addition to the results obtained by us we also used those obtained by the Central Aerohydrodynamic Institute for one type of constantan wire [4] in its hard and anneal conditions. In the type 1-P-10 strain gauges, made by the Institute, viniflex and BF-2 glues were used without a paper base, the wire being glued straight onto 30KhGSA steel forms for which the linear expansion coefficient may be taken as $\alpha_1 \simeq 11 \cdot 10^{-6}$. The sensitivity coefficient of the strain-gauge is $K \simeq 2.07$. Figure 3 shows the temperature characteristics of loose wire samples and glued-on strain gauges copied from [4]. The figures by the curves denote the annealing temperatures.

TABLE 2

Wire materials	Transducers $\beta_C \cdot 10^{-6} \frac{1}{°C}$	Wire $\beta_0 \cdot 10^{-6} \frac{1}{°C}$	$\alpha_0 \cdot 10^{-6} \frac{1}{°C}$
Driver Company's hard constantan 0.03 mm wire	−50	−51.5	11.2
Driver Company's "cupron" enameled 0.026 mm wire	−25	−26	11.5
MNMts 40-1.5 hard constantan 0.03 mm wire of the OTsM plant	−15.5	−16	11.8
"Cupron" constantan 0.026 mm wire, annealed (to condition 1)	+ 2.5	+ 2	11.7
The same, annealed (to condition 2)	−7	− 6.5	12.3
TsNIIChM chrome-aluminum OKh25Yu$_5$ hard alloy 0.05 mm wire (experimental consignment)	+ 9	+ 6	10.9
The same, annealed at 800°C for 2 hr	+29.5	+29	11.8
Hard constantan 0.03 mm (experimental TsAGI) wire	−41	−45	10.0
The same, annealed at 350°C	−14	−10	13.0
" " annealed at 390°C	+ 3	+ 7.5	13.3
" " annealed at 420°C	+10.5	+12.5	12.0

From the temperature characteristics of Figs. 1, 2, and 3, the temperature coefficients of resistance β_t and β_0 were calculated for the glued-on and loose wire in the temperature range of 20-40°C which is important from the practical point of view.

The linear expansion coefficients α_0 of winding shown in Table 2 were calculated by means of formula (3).

The experimentally obtained values for coefficient of linear expansion α_0 of the strain gauge windings of different (hard and annealed) constantan wires, glued to the samples by means of the most commonly used glues (nitrocellulose, and BF-2) were found to equal approximately $\alpha_0 \simeq (12 \text{ to } 13) \cdot 10^{-6}$, i.e., closely approximating the coefficient of linear expansion of the form material which is $\alpha_1 = 12 \cdot 10^{-6}$.

Experience of the Central Committee of Heavy Industry and the Central Aerohydrodynamic Institute confirms that it is impossible to select values of the linear expansion coefficient of $\alpha_0 = (14 \text{ to } 17) \cdot 10^{-6}$ for calculating resistance increments due to temperature in glued-on strain gauges. When testing components made

of materials with a linear expansion coefficient of $\alpha_1 = (11 \text{ to } 12) \cdot 10^{-6}$ values of $\alpha_0 = (12 \text{ to } 13) \cdot 10^{-6}$ should be used. These materials include, for instance, steels of the pearlite type such as carbon, alloy, constructional, and other steels, which are widely used in engineering.

Experiments have shown that for above materials it is possible to make partly thermally compensated ("self-compensated") strain gauges out of a single type of wire whose temperature coefficient of resistance is in the range of $\beta \simeq +(2 \text{ to } 4)\ 10^{-6}$. Such a strain-gauge constantan wire can be obtained by an appropriate heat-treatment of many hard types of wire, which are normally produced by the manufacturing plants, providing the supplied wire has negative temperature coefficients of resistance.

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A KINEMETRIC CONTINUOUS RECORDING METHOD FOR LINEAR AND ANGULAR DISPLACEMENTS

I. G. Kolker

Translated from Izmeritel'naya Tekhnika, No. 4, pp 26-27, April, 1960

Disadvantages of the kinemetric method of measuring deformations include a considerable complexity in deciphering a large number of frames and a very large consumption of films due to the high-speed filming of rapid processes.

The application of the frameless method of recording linear and angular displacements (deformations) completely eliminates above defect. This kind of filming can be carried out by means of a normal camera if the film is made to move continuously and a color or light sign, placed on the spot where deformation is being measured, is filmed through a narrow slit in an opaque shutter fixed in the focal plane.

Thus, with a datum point marked at the place of deformation measurements, it is possible to measure displacements with respect to the three axes of coordinates. In fact, by sighting displacements through slit AB (Fig. 1) along the axis of the datum line, the continuously moving film will record lines whose coordinates will be proportional to the displacements and deformation under consideration (Fig. 2).

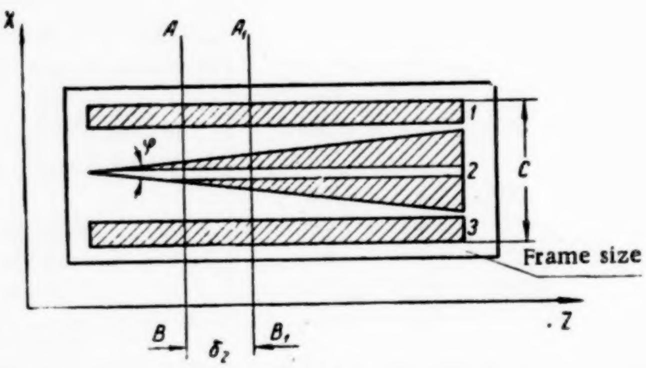

Fig. 1.

If in addition to displacements along the X-axis there also arise deformations along the Z-axis, they will produce a relative displacement of the image by δ_z (Fig. 1). The relative displacement of the datum wedge with respect to the slit will produce a widening of the middle line by $\Delta = 2\delta_x$ (Fig. 2).

The relation between δ_x and the actual displacement along the Z-axis is represented by the formula:

$$\delta_z = \kappa\delta_x \cot\frac{\varphi}{2}.$$

where K is the scale coefficient; δ_x – half the widening of the middle path; φ – the angle of the wedge; δ_z – the displacement along the Z-axis.

The value of the error in measuring deformations along the Z-axis is determined by the value of angle φ. If the angle is 90° the error of measurement in the X and Z directions will be the same; if $\varphi > 90°$, the error in the Z direction will be smaller than that in the X direction.

Displacements along the Y-axis will produce variations in the scale of filming. Thus, the distances between paths 1, 2, and 3 on the film (Fig. 1 and 2) and the width of the paths will vary proportionately to the displacements along the Y-axis.

It is easy to select the appropriate optical conditions in order to obtain the required accuracy in measuring displacement along the Y-axis.

In addition to linear displacements (deformations) it is also possible to record twisting deformations by means of this method. For this purpose it is necessary to film with a shutter which has two slits in it. The turning angle can be calculated from the formula below which is based on the difference in displacements along the X-axis obtained from the two slits:

$$\tan\alpha = \frac{h_1 - h_2}{b},$$

where h_1 and h_2 are the displacement along the given axis calculated from the recordings corresponding to the first and second slits; $\underline{b}$ is the distance along the base.

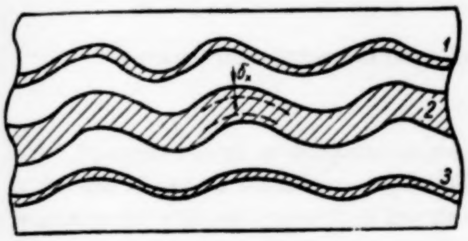

Fig. 2.

This method was tested out by measuring the deformation of an airplane strut during take-off and landing.

The datum plate was fixed to the lower part of the strut and a 3 mm wide white line drawn on the plate, parallel to its axis.

The moving-picture camera was rigidly fixed in the hatch of the main leg of the chassis and sighted on the datum plate below it. The camera frame was covered by an opaque shutter with an approximately 0.6 mm wide slit cut in it parallel to the Z-axis.

Thus, the white stripe of the datum plate was projected onto the film as a thin line 0.15 mm wide and 0.6 mm long. When the film was in motion and the strut stationary, a dark straight line 0.15 mm wide was projected on the film.

Fig. 3.

When, during the take-off or landing the strut deviated from its neutral position, a corresponding displacement was produced by the line on the film.

Damped vibrations of a cantilever strip were recorded in a similar manner (Fig. 3).

The required speed of the film movement can be calculated from the resolution of the film and the frequency of variations of the process under consideration.

With a frequency of parameter variations of the order of 25-30 cps and a resolution of the film and the optical device of the order of 15 lines per 1 mm, a speed of film movement of 2-2.5 mm/sec is sufficient.

According to the given values of the speed of film propulsion, the degree of illumination of the datum plate and the selected position of the diaphragm, the required size of the slit can be determined from the formula

$$\frac{\Delta T}{\kappa c d} > \frac{\Delta S}{V},$$

where ΔS is the width of the slit, V – the speed of film propulsion, k – the coefficient of proportionality, which depends on the frequency, the film sensitivity, luminosity, optical arrangements, and the degree of illumination

of the filmed object. ΔT – half a period of the recorded displacement variations; $\underline{c}$ – the required number of recorded discrete values of the variable amplitude, $\underline{d}$ – the ratio of the maximum gradient in the rise of the parameter under investigation to its mean value.

SUMMARY

The accuracy in measuring deformations depends on the correct selection of initial parameters and, in the first place, on the quality of the optical device. The calculation of the error in kinematic measurements does not present any difficulties. Thus, the suggested method provides a continuous recording of the variations in linear and angular displacements by means of a kinemetric method with a sufficient accuracy for dynamic processes.

THERMOTECHNICAL MEASUREMENTS

METHODS FOR TESTING THERMAL INERTIA IN THERMOCOUPLES AND RESISTANCE THERMOMETERS

G. M. Levin and V. I. Vol'mir

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Thermal inertia of temperature-measuring devices is one of their most important characteristics. Hence, in the specifications for thermocouples (GOST 6616-53) and resistance thermometers (GOST 6651-53*) the requirements with respect to their inertia are determined and methods for its measurement described.

The value of thermal inertia obtained by means of these methods can only serve for evaluating the quality of the instrument assembly and cannot be taken as a reliable characteristic of their operational properties [1].

Theoretical and experimental investigations have shown [2, 3] that the physical definition of inertia given in GOST 6616-53 and in the obsolete GOST 6651-53, and its basic nominally 10% "underrated" value, as well as the method recommended for its measurements and for conversion to other "underrated" values, are not sufficiently sound scientifically and are superficial.

These methods are based on an incorrect assumption that a steady thermal state is established when the thermal element of the instrument is immersed in the thermostatically controlled medium, without taking into consideration the relation of inertia to the conditions of heat exchange, and provide for tests only for very high values of the heat-transfer factor α, which are often far-removed from the actual operating conditions of the

TABLE 1

Instruments	n	lnA
Commercial thermocouples and resistance thermometers	1.0-1.5	8.5-10
Thermocouples and resistance thermometers in quartz and glass jackets	0.7-0.8	5.5-6.5

instruments. Thus, for instance, the recommended testing temperatures (100°C for thermocouples and 0°C for resistance thermometers), do not cover the working range of temperatures on the one hand, and on the other lead to measurement errors due to protruding parts and the temperature difference between the heating (cooling) medium and the surrounding air, i.e., to conditions which do not correspond to a thermally stable state.

The necessity for testing assembled and calibrated instruments, and determining their inertia by means of their readings, in the first place increase the errors of the method and in the second place does not provide the possibility of measuring the thermal inertia of the thermal element detached from its "transmission mechanism", the protruding parts.

*Replaced by GOST 6651-59 in which a different definition of inertia is given and a different method for measuring it described, a method which approximates the one described in this article. Editor's note.

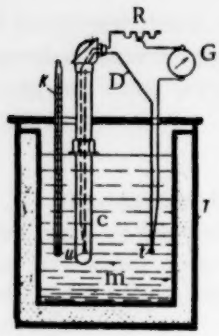

Fig. 1.

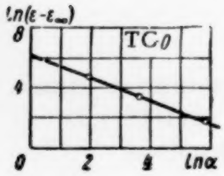

Fig. 2.

Finally, these methods can provide false ideas about the properties of the instruments, the values of their inertia, about their lagging or time required to obtain a steady reading, and they can also mislead designers who are attempting to account for the thermal inertia of the temperature measuring devices, or thermal elements in automatic control and regulation systems.

The inertia characteristics and conditions of their measurement obtained by these methods can result in an underestimation of the lagging inside the thermal element and its jacket, as well as of the thermal capacity of components under different conditions of heat exchange with the ambient medium, of the effect of immersion, thermal conductivity along the instrument and of other factors.

The above defects and the stricter requirements with respect to a correct evaluation of thermal inertia, due to the application of modern techniques, require a revision of the existing methods and their replacement by more precise and theoretically correct methods. The universal method of a stable thermal state [2], with certain additions and corrections, can be considered suitable for the purpose.

The universal method of a stable thermal state provides a physically sound and reliable criterion of thermal inertia, the characteristic lag curves (the relation of the thermal inertia index ϵ to the heat dissipation factor α) which can serve as a basis for a correct classification and selection of thermal elements and devices for measuring temperature, and for a relative evaluation of their thermal inertia at different intensities of heat exchange with the surrounding medium. This technique of determining the thermal inertia index ϵ makes it possible to eliminate almost completely the effect of protruding parts and that of the heat exchange of the instrument with the surrounding air, and to investigate the properties of the instrument as a whole and of the thermal element detached from the remaining components, and to take into consideration the nature and duration of the thermal condition preceding the stable state, to evaluate the relation of ϵ, and the precision of its measurement to the design peculiarities of instruments, their immersion, etc.

For a practical application of ϵ, for the purpose of evaluating the lag in the readings of instruments under working conditions or for calculating the time it takes their readings to stabilize, the characteristic curve plotted at room temperature , a constant ambient temperature and constant heat dissipation, should be supplemented by individual testing of instruments under working conditions.

The technique of plotting the characteristic curves can be greatly simplified by using an empirical relationship which satisfactorily represents these curves:

$$\varepsilon - \varepsilon_{\infty} = A\alpha^{-n}, \tag{1}$$

where ϵ_{∞} is the minimum value of ϵ for a given instrument, obtained for $\alpha \rightarrow \infty$; A and n – parameters determined graphically on the basis of a logarithmic anamorphosis (1):

$$\ln(\varepsilon - \varepsilon_{\infty}) = \ln A - n \ln \alpha, \tag{2}$$

where n is the angular coefficient of curve (2); lnA – a section of curve (2) on the axis $\ln(\epsilon - \epsilon_{\infty})$.

On the basis of (1) and (2) it is possible to simplify the technique of plotting characteristic curves and check the accuracy of the experiment. The value of ϵ_{∞} and two values of ϵ for different heat-exchange conditions (for instance in a chamber of still air or still water) are measured. The corresponding values of α are either determined by means of an alpha calorimeter [3, 4] or taken from tables [3]. Next a graph of the relation between $\ln(\epsilon - \epsilon_{\infty})$ and $\ln\ \alpha$, is plotted which according to (2) should be a straight line. If it is required to check the accuracy of previous determinations, yet another value of ϵ is measured (for instance, in transformer oil) and for the corresponding value of α another point is plotted on the graph. If the point falls on the previously drawn straight line the reliability of the experiments is confirmed.

Having determined graphically according to (1) the values of lnA and n, it is possible to compare them with the tentative data of Table 1 compiled from the results obtained in our experiments.

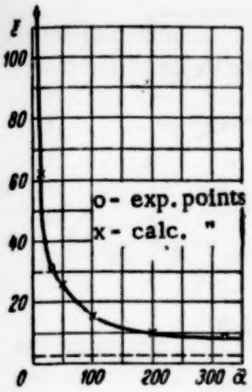

Fig. 3.

An agreement between the values of lnA and n thus obtained and those given in Table 1 for a given group of instruments once again confirms the correctness of their determination.

A complete characteristic curve can then be plotted from (1) by taking a number of values for α and substituting the experimentally obtained values ϵ_{∞}, A, and n in (1).

The example given below illustrates the universal method of a stable thermal state and the possible applications of the values thus obtained in the checking technique.

Example. In the course of checking operations it was found necessary to: a) compare the thermal inertia of a P. G. Strelkov reference resistance thermometer (denoted by TS-O) with that of a reference copper-constantan thermocouple (TC-O), both instruments are in quartz jackets 5 mm in diameter; b) establish the maximum permissible rate of temperature variations v_{max} in the thermostat, when comparing the TC-O with the TS-O instrument and also the reference mercury in glass thermometer (MG-O) with the TC-O instruments for an error due to the thermal inertia of the thermometers, not exceeding $\pm 0.01°C$.

The values of ϵ were determined by means of the arrangement shown in Fig. 1. The thermal element of instrument C was immersed in the thermostatically controlled medium M, whose temperature t was maintained constant throughout the experiment within $\pm 0.1°C$ and checked on thermometer K. A differential copper-constantan thermocouple D connected through a resistance box R to a mirror galvanometer G, was used for measuring temperature difference ϑ between the temperature of the medium (t) and that at a selected point of the thermocouple (u). Simultaneously time intervals τ were registered by means of a stop watch or a chronograph. The steady-state thermal condition is characterized by a linear section of the graph of $\ln \vartheta = f(\tau)$, and from it ϵ is found as the cotangent of its angle of slope with respect to the τ axis.

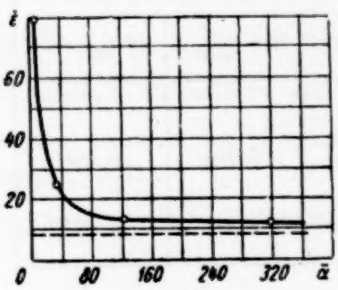

Fig. 4.

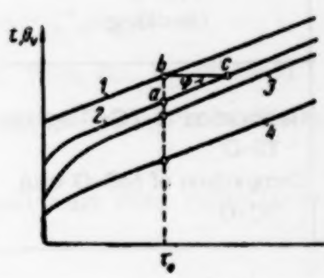

Fig. 5.

The values of ϵ for the TC-O instrument were measured in four media: in stirred water (ϵ_{∞}), still water, still transformer oil, and still air. Then a graph of the relation $[\ln(\epsilon - \epsilon_{\infty})] = f(\ln\alpha)$ was plotted with values of α previously obtained for these media by means of similar instruments (Fig. 2). The experimental points coincide well with the calculated curve. Having found from this graph the values of $\ln A = 6.2$ and $n = 0.78$ we compared them with Table 1 values and became once more convinced of the precision of the experiment. Next having chosen the values of $\alpha = 15, 50, 100$, and 200 we calculated from (2) the corresponding values of ϵ (Table 2) and plotted a characteristic lag curve for the TC-O instrument (Fig. 3).

An example of calculating the value of ϵ for a TC-O instrument: $\ln A = 6.2$, $n = 0.78$, $\epsilon_{\infty} = 2.2$. Let us substitute in (2): $\ln(\epsilon - 2.2) = 6.2 - 0.78 \ln\alpha$. Let us take $\alpha = 100$. Then $\ln\alpha = 4.605$, $\ln(\epsilon - 2.2) = 6.2 - 0.78 \cdot 4.605 = 2.6$; $\epsilon = 15.7$ sec.

The characteristic curve for the TS-O instrument (Fig. 4) was plotted in a similar manner. Here $n = 0.78$ and $\ln A = 5.5$. The comparison of curves in Figs. 3 and 4 shows that for small values of α the TC-O instrument has a larger inertia, but for medium and large values of α, the resistance thermometer TS-O has a larger inertia.

TABLE 2

Medium	α, kcal/m^2·hr·deg	ϵ sec.	$\epsilon - \epsilon_\infty$, sec	lnα	ln($\epsilon - \epsilon_\infty$)
Stirred water	∞	2.2	–	–	–
Still water	319	8.2	6	5.77	1.79
Calculated values	200	10.1	–	–	–
" "	100	15.7	–	–	–
" "	50	25.5	–	–	–
Still oil	33.7	31.1	29	3.52	3.37
Calculated values	15	62.1	–	–	–
Still air	7	114	112	1.95	4.72

TABLE 3

Instrument	ϵ_λ for α, kcal/m^2 · hr · deg			
	50	100	300	∞
TS-O	17	13	8.5	5
TC-O	23	13	6.5	1.5
MG-O	81	48	28	22

TABLE 4

Type of checking	v_{max} for α, (kcal/m^2 · hr · deg			
	50	100	300	∞
Calibration of TC-O against TS-O	0.025	0.043	0.079	0.120
Comparison of MG-O with TC-O	0.007	0.012	0.021	0.027

Determination of v_{max}. The temperature versus time graphs of the medium and the instruments under consideration have the shape shown in Fig. 5. Here 1 is the graph of the thermostat temperature and 2, 3, and 4 those of the TC-O, TS-O, and MG-O instruments, respectively.

Let us now assume the following heat exchange conditions with the medium: α = 50, 100, 100, and ∞. Next, considering the linear variation of temperature, let us introduce the corresponding corrections to the values of ϵ [7], taking a nominal coefficient of 0.9 for α = 50 and 100 and a coefficient of 0.7 for α = 300 and ∞.

We shall then obtain the following values for ϵ_λ in sec (Table 3).

Remarks. The data for the MG-O instrument were taken from a paper which was published in part [5].

Thus, for calibrations of the TC-O against the TS-O instrument at α = 50 to 100, TC-O will have the greater inertia, and at α = 300 to ∞, the TS-O will have the greater inertia. In comparing the MG-O, and probably many other liquid-in-glass thermometers, with the TC-O instrument, the former have the greater inertia for all values of α.

Curves 2, 3, and 4 of Fig. 5 show the relation between the bulk mean temperature Θ_v of the thermal elements and time. For any instant(as for instance, τ_1) it is possible to write

$$ab = t - \Theta_v = \vartheta_v. \tag{3}$$

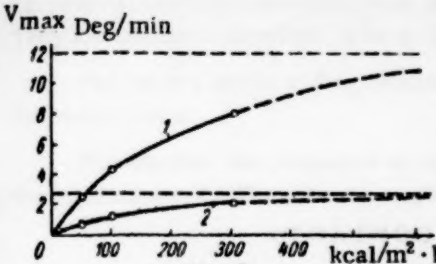

Fig. 6.

The rate of the ambient temperature variations $v = dt/d\tau = \tan\varphi$

Hence,

$$bc = \frac{\vartheta_v}{v} = \varepsilon_\lambda. \tag{4}$$

By substituting in (4) the value of ϵ_λ taken from Table 3, and changing ϑ_v for the permissible error $\delta = \pm 0.01°C$ adopted by us, let us calculate the corresponding value of v_{max} in deg /min (Table 4) and let us plot (Fig. 6) curves of comparison of the TC-O with the TS-O (1) and of the MG-O with the TC-O instruments (2).

By using Table 4 it is also possible to calculate the corrections Δ which should be used when two temperature measuring instruments (denoted I and II) with different ϵ_λ are being compared for given values of v and α;

$$\Delta = \delta_I - \delta_{II} = v\,(\varepsilon'_\lambda - \varepsilon''_\lambda). \tag{5}$$

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A DEVICE FOR TESTING THE QUALITY OF SLIDING CONTACTS WHEN MEASURING THE TEMPERATURE OF ROTATING OBJECTS

R. Z. Alimov

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The measurement of various physical quantities (for instance, temperature or tension which arises in discrete points of rotating bodies) in rotating details, by electrical methods, requires some type of lead-outs with sliding contacts. It is known [1] that the presence of sliding contacts in an electrical circuit can distort considerably the measurement results. It is, therefore, interesting from the point of view of evaluating the nature and size of these distortions to measure simultaneously in two similar electrical circuits, one of them being without contacts. This problem can be solved for thermocouple temperature measurements by means of an equipment consisting of a toroidal electrical oven 1 and a rod and crank mechanism (Fig. 1), driven through shaft 2 by a motor with a controlled speed. The oven which can be heated up to any temperature between room temperature and 1000°C carries the hot ends of two thermocouples 3 and 4 which are matched for their calibration characteristics. The appropriately insulated leads of thermocouple 3 pass inside steel tube 5 which is firmly fixed to the head of connecting rod 6, then run along the rod to slider 7 and from it in a flexible connection to switch 8. Thus, the electrical circuit of the thermocouple has no sliding contacts.

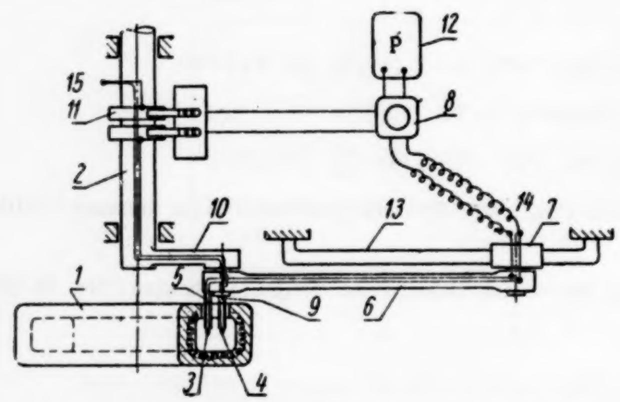

Fig. 1. Schematic of the equipment. 1) Round electrical oven; 2) shaft; 3) reference thermocouple; 4) thermocouple under test; 5) and 9) steel tubes; 6) connecting rod; 7) slider; 8) thermocouple switch; 10) crank; 11) sliding contact leadout; 12) potentiometer; 13) guide rail; 14 and 15) thermocouple cold junctions.

The leads of thermocouple 4 pass inside steel tube 9 which is connected to the journal of crank 10, and then along the crank 10 and shaft 2, which are rigidly interconnected, to slip rings 11 whose brushes are connected to switch 8. Thus, the electrical circuit of thermocouple 4 contains sliding contacts.

When the crank and rod mechanism is in motion, the hot end of thermocouple 4 is displaced along a circumference of radius R equal to the length of the crank, and that of thermocouple 3 along a curve which approximates a circumference of the same radius, and at the same time it revolves about its axis at a rate $\underline{n}$ equal to that of the shaft. An important property of this arrangement is that the distance between the two thermocouple junctions does not change in motion. In order to ensure a similar heat exchange with the surrounding medium, the thermocouple junctions are placed as close as possible to each other.

The maximum length of the steel tubes 5 and 9 and the depth of their immersion in the oven are determined mainly by the strength of the tubes in resisting bending under the applied centrifugal force. In above equipment the tubes were 150 mm long with an external diameter of 6 mm and thickness of the walls 1.5 mm.

Chromel-alumel thermocouples were used in this experiment. Their cold junctions 14 and 15 remained in air. They are assumed, therefore, to be at the temperature of ambient air.

The quality of the sliding contacts and the value of the stray emfs produced by them is established in the following manner.

The electric oven is heated up until the required temperature is reached. Next the shaft 2 is rotated at the required speed. Then thermocouples 3 and 4 begin to rotate together with the crank and the connecting rod head to which they are fixed. Since the thermocouples are under similar heat-exchange conditions they attain very closely the same temperature in a stable thermal state. The emf of the thermocouples is measured on potentiometer 12 which is switched to them in turn by means of switch 8. The comparison of the emfs measured under different operating conditions provides the contact characteristic of the slip rings under test.*

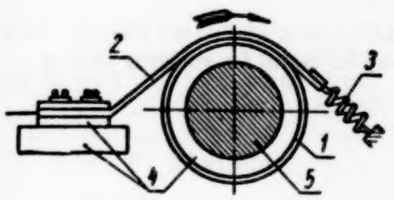

Fig. 2. Schematic of the sliding contact. 1) Copper ring; 2) strip copper brush; 3) spring; 4) insulating details; 5) shaft.

Above equipment was made and successfully used up to temperatures of 1000°C and sliding speeds of brush up to 10 m/sec at the Resistance of Materials Department of the Kazan' Aviation Institute. By means of this equipment, among other things, the characteristics of the sliding lead-outs (Fig. 2) were studied. The slip rings and brushes were made of strip copper M1 with the appropriate mechanical treatment. During operation the contacts were periodically covered with graphite powder in order to decrease friction and in the intervals between testing they were carefully cleaned with a chamois cloth. The brushes were pressed against the rings by means of helical springs. The spring pressure was adjusted to obtain the most steady potentiometer reading of the emf of thermocouple 4 (Fig. 1). The mean value of the pressure of the brushes against the contact surface was of the order of 1 kg-wt/cm^2. The speed of the brush movement was controlled by changing the velocity of the shaft rotation and the diameter of the slip rings.

Figure 3 shows the characteristic of the slip ring tested in the manner described above. The larger emf values were produced by thermocouple 4. (Fig. 1).

The curves were plotted for the arithmetic mean values of ΔE calculated on the basis of a large number of measurements taken at different times. The dispersion of certain points amounted to 50% of the mean values of ΔE.

During the experiments no substantial effect of the thermocouple hot junction temperature on ΔE was observed. The numerical values of ΔE did not change noticeably when thermocouples 3 and 4 were interchanged (Fig. 1), thus proving the small effect on the heat exchange due to the rotation of thermocouple 3 about its axis. The latter conclusion does not contradict the experimental investigations dealing with the heat exchange in rotating cylinders [2, 3]. In fact the junction of thermocouple 3 with the adjoining leads can be considered as a cylinder with hot air flowing round it in a transverse stream. When the cylinder is rotated, the speed of the points on its surface with respect to the air stream flowing round the cylinder is increased on one side, whereas on the other side, where the points are displaced in the same direction as the air stream, their relative speed is decreased. Thus, the mean speed of the cylinder surface points with respect to the air, remains the same. It is known [2] that the value at of the heat dissipation factor at a point depends, with the remaining conditions unchanged, on the speed at that point of the air stream flowing round it, irrespective of the manner in which that movement is achieved, either by rotating the cylinder about its axis or by making the air flow rotate about the cylinder axis, i.e., the heat-exchange mechanism remains the same in either case. It is, therefore, possible to consider that the mean heat dissipation by convection is the same in either case. Both thermocouples are also under similar conditions, with respect to dissipation through radiation.

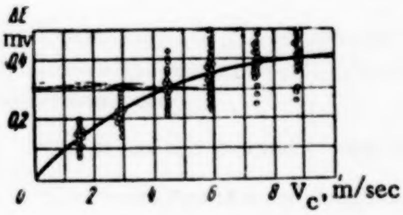

Fig. 3.

*In this instance the contact characteristic is understood to be the relation of the difference between the two thermocouple emfs ΔE to the sliding speed V_c of the contacts with other conditions remaining constant.

Above experiments have shown that the dispersion of points is due to changes in thermocouple 4 readings caused by the instability of the sliding-contact operation. The readings of thermocouple 3 corresponded to the stable thermal state of the oven and were relatively stable.

In these experiments with a crank radius of 200 mm and the connecting-rod length of 800 mm, the shaft rotated with a speed not exceeding 500 rpm. The crank and rod mechanism could, therefore, have a relatively simple design and its manufacture did not present any difficulties. However, if experiments have to be conducted at a higher speed the mechanism must be designed and made according to the requirements of high speed piston or steam engines.

SUMMARY

These experiments lead to the conclusion that the above equipment may be useful for studying sliding contacts.

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ELECTRICAL MEASUREMENTS

A BRIDGE FOR COMPARING STANDARD AND REFERENCE RESISTORS IN THE RANGE OF 0.001 to 100,000 ohms

V. P. Shigorin

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In the D. I. Mendeleev All-Union Scientific Research Institute, comparison of reference and standard resistors was carried out to date with compensation or bridge (single or double) circuits and equipments using differential galvanometers.

All these types of equipment have considerable defects, the most important of them being the instability of electrical connections between components, the lack of a general thermostatic and thermal control and in the majority of cases, lack of sensitivity.

The comparison of resistors by means of compensation devices is further complicated by the necessity of maintaining stable sources of emfs. Moreover, the shunting of resistors, required in the comparison process, produces a systematic error, due on the one hand to variations in the current of the main circuit, and on the other to the drop of voltage at the shunting resistor terminals. The first error amounts in comparing resistors between 1 and 100 ohms to 0.0001-0.001%. The second becomes particularly noticeable when comparing reference resistors of a nominal value of 0.01 ohm. It then amounts to 0.005-0.006%.

These equipments operate in an unbalanced condition thus making it necessary in working out the results to use interpolation formulas. All these circumstances make the comparison methods complicated and slow.

The All-Union Scientific Research Institute of Metrology has developed a new equipment for comparing reference and standard resistors consisting of a compound instrument, a completely balanced comparator-bridge.

The existence of a single source of supply and the independence of results from the stability of the source emf, constitute considerable advantages of this comparator as compared with the compensation equipments which were to date considered to be the most accurate in the Institute.

Constructionally the comparator-bridge is a compound instrument placed in a thermostatically controlled bath filled with transformer oil. This bath also contains a frame with a perforated ebonite base for mounting the resistors under test.

The automatic thermal control device with two mixers provides a constant temperature of 20 ± (0.01 to 0.03)°C.

The most important resistance components of the bridge are made of manganin with a temperature coefficient not exceeding 0.0015% and are hermetically sealed. All the resistance coils were heat-treated during manufacture and naturally aged.

The comparator can be connected as a single or double bridge with arms ratios from 1 to 0.1 (or 10), thus making it universally applicable.

The schematic of the bridge is shown in Fig. 1.

The double bridge has equal main and auxiliary ratio arms and series-connected equalizing resistors, thus considerably simplifying its balancing and providing interchangeability of the arms.

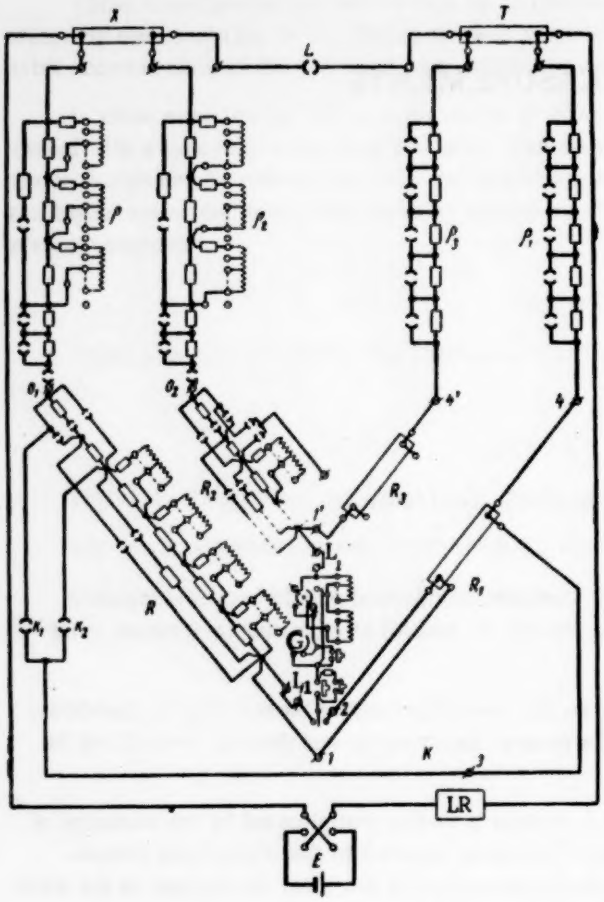

Fig. 1. R and R_1 are, respectively, the adjustable and constant main (external) ratio arms of the double bridge; R_2 and R_3 are, respectively, the adjustable and constant auxiliary (internal) ratio arms; X and T are respectively compared and tare (auxiliary) resistors, connected for comparison by the substitution method; ρ and ρ_2 are equalizing resistors connected to the adjustable arms of the bridge; ρ_1 and ρ_3 are equalizing resistors connected to the constant arms of the bridge; K is the link for shorting the main (external) arms of the bridge; L is the link in the comparison circuit of the bridge; L_1 and L_2 are the links in the galvanometer circuit; G is the galvanometer, E the storage battery; O_1, 1, 2, 3, and 4 (O_2, 1', 3', and 4') are terminals in the bridge circuit; LR is the load resistance.

The adjustable arms $R(R_2)$ consist of four modified decades of the Weidner-Wolf type [1] in steps of 0.1, 0.01, 0.001, and 0.0001 ohms and three resistance coils with a nominal value of 12.5, 50, and 900 ohms (Fig. 2).

Owing to the special values assigned to the resistors of the adjustable arm all the ratios of arm R to arm R_1 can be read directly in millionths or ten-millionths of the nominal ratio. Thus, the entire technique of measurements is greatly simplified, especially the working out of the results which only involves the simplest arithmetical operations.

The resistance of the adjustable arms $R(R_2)$ can be changed be means of decade switched in the limits of 49.4445 and 50.5555 ohms. Hence, the adjustable arm provides a resistance variation of ±0.5555% with respect to nominal values of 25 and 100 ohms, of ± 1.111% with respect to the nominal values of 50 ohms and of ± 0.05555% with respect to the nominal value of 1000 ohms.

In order to eliminate the effect of the terminal resistances of coils and connections on the accuracy of the results, the bridge-comparator circuit is provided with the possibility of step by step balancing [2, 3].

For this purpose additional elements consisting of equalizing resistors ρ, ρ_1, ρ_2, and ρ_3 are included in the circuit as well as links L and K which are provided with plug-in contacts.

"Vibrator" plant galvanometers M21 and M107 are used as balance indicators in the bridge.

The comparison of standard and reference resistors by the substitution method is carried out by connecting in turn the resistors being compared into arm X (see Fig. 1) and balancing the bridge by means of the adjustable arm $R(R_2)$.

Let us assume that several resistors of the same nominal value $X_1, X_2, \ldots X_n$, have to be compared and that the values of X_1 and X_2 are known. From the conditions of the bridge balance we obtain:

$$X_1 = \frac{T}{R_1} R_m(1 + r_1 - r_m)$$

$$X_2 = \frac{T}{R_1} R_m(1 + r_2 - r_m).$$

. . . .

$$X_n = \frac{T}{R_1} R_m(1 + r_n - r_m).$$

where $r_1, r_2, \ldots r_n$ are readings on the dials of the decade switches in relative values; R_n – the nominal value of the adjustable arm resistance; r – reading corresponding to the nominal value of the adjustable arm (according to the calibration $r_m = 5555$).

Equation (1) can be reduced to the form

$$N(1+x_\kappa)=\frac{N(1+t)(1+r_\kappa-r_m)}{1+\rho}, \tag{2}$$

where x_k, t, and ρ are the relative deviations of resistors X_k, T and R_1 from their nominal values; and N is a nominal value.

After transformation of (2) we obtain:

$$\begin{aligned} x_\kappa = t+(r_m-r_m)-\rho+t\,(r_\kappa-r_m)-\rho t-\rho\,(r_\kappa-r_m)+ \\ +\rho^2-\rho t\,(r_\kappa-r_m). \end{aligned} \tag{3}$$

Neglecting the last term which is of the third order of magnitude, and the second order of magnitude, expression $(t-\rho)\,(r_k-r_m)$, we obtain

$$x_\kappa=r_\kappa+(t-r_\kappa-\rho+\rho^2-\rho t). \tag{4}$$

In (4) the quantity in brackets is constant for a given series of measurements and it is therefore possible to write

$$\begin{aligned} x_1&=r_1+C, \\ x_2&=r_2+C, \\ &\cdot\ \cdot\ \cdot\ \cdot\ \cdot \\ x_n&=r_n+C, \end{aligned} \tag{5}$$

where C is constant for a given series of measurements.

Since X_1 and X_2 according to definition are known resistances, C can be determined from the first two equations as an arithmetic mean. By substituting this value of C into the remaining equations of system (5) the relative deviations of the unknown resistors from their nominal values are determined.

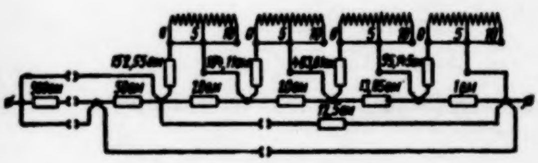

Fig. 2. (OM=ohm)

The permutation method consists of a repeated measurement (bridge balancing) with the resistors under test interchanged, thus eliminating the systematic error of the ratio arms in the working out of the measurement results. Let us assume that it is required to compare by the permutation method two resistors of nominally equal values X_1 and X_2. The balance conditions of the bridge for either connection can be expressed by the equations

$$\begin{aligned} X_1&=X_2\frac{R_n}{R_1}\,(1+r_1-r_m), \\ X_2&=X_1\frac{R_n}{R_1}\,(1+r_2-r_m). \end{aligned} \tag{6}$$

By multiplying these equations term by term and neglecting small quantities of the second and higher orders we obtain:

$$X_1=X_2\left(1+\frac{r_1-r_2}{2}\right) \tag{7}$$

or in relative terms

$$x_1 = x_2 + \frac{r_1 - r_2}{2} + x_2\,\frac{r_1 - r_2}{2}. \tag{8}$$

It is obvious that in comparing standard and reference resistors it is also possible to neglect the last term and thus obtain the final expression

$$x_1 = x_2 + \frac{r_1 - r_2}{2}$$

The computation formulas (5) and (9) have been derived for a single bridge, but owing to the step-by-step method of balancing the bridge they are also applicable to a double bridge.

The measurement of resistors which are not equal to $10^{\pm k}$ ohms (k being an integer) is made by means of the bridge ratio standard. The ratio standard consists of 10 sections of 100 ohms and 10 sections of 10 ohms, each connected in series. The standard is calibrated beforehand (in ratio units) and used for setting up an accurate ratio of the compared resistors, one of which is the resistor under test X and the other the reference (standard) resistor T.

Measurements are made by the substitution method in two steps, first with the compared resistors connected to the bridge (reading r) and then with the ratio standard connected (reading r_s). Accordingly, two equations can be written:

$$\begin{aligned} \frac{X}{T} &= \kappa\,(1 + r - r_\kappa), \\ \frac{X_S}{T_S} &= \kappa\,(1 + r_S - r_\kappa) \end{aligned} \tag{10}$$

or in relative terms

$$\begin{aligned} x &= t + r - r_\kappa + t\,(r - r_\kappa), \\ x_S &= t_S + r_S - r_\kappa + t_S\,(r_S - r_\kappa). \end{aligned} \tag{11}$$

In (11) the last terms, which are second-order quantities, can be neglected, then we have finally

$$\begin{aligned} x &= t + r - r_\kappa, \\ r_\kappa &= r_S + t_S - x_S\,. \end{aligned} \tag{12}$$

where $\underline{x}$ and $\underline{t}$ are the relative deviations of the resistors being compared from their nominal values; x_s and t_s are the relative deviations of the parts of the ratio standard connected respectively to arms X and T; r_k is the reading corresponding to the nominal ratio $\underline{k}$ of the bridge arms (R_m/R_{1m}) and the resistors under comparison (X_m/T_m).

The comparator is connected as a single or double bridge according to the value of the measured resistors. When the ratio standard is used, however, (reading r_s) the comparator is always used in the single bridge connection.

When measurements obtained under (12) are being worked out it is necessary to take account of the signs in front of readings $\underline{r}$ and r_s. If the measured resistor was connected to arm T and the reference resistor to arm X the readings should be taken with negative signs.

Errors of the bridge-comparator. Owing to the adopted comparison methods the bridge has practically no systematic errors. This is confirmed convincingly by the calibration results of the adjustable arm, the comparison of results obtained by the two methods (substitution and permutation) and the comparison with the results obtained by compensation measurements.

1. The error due to inaccuracies in the manufacture of the comparator resistors is almost completely eliminated by the substitution and permutation methods. The correction of the comparator readings does not

0.00001% if the difference between the arms ratios ($X/T-R/R_1$) does not exceed 1% of the nominal value.

2. The error due to the resistance of connecting conductors, the contact resistance and its variations, is also almost completely eliminated owing to comparison methods employed, the step by step balancing of the bridge and the use of specially designed Weidner-Wolf resistance decades in the adjustable arm.

3. The effect of constant thermal emfs. arising in the measuring circuit, is eliminated in balancing the bridge by means of the "false zero" method, which is based on the theorem of the independence of the galvanometer and supply diagonals when the bridge is close to its balanced condition.

4. The error due to insufficient sensitivity affects the accuracy of the bridge only when resistors of a nominal value of 0.001 ohms or 100,000 ohms are being compared. In these instances the error may reach values of the order of 0.00005%.

5. The error due to current leakages is practically eliminated owing to the comparison method and the high-quality insulation of the current carrying components.

6. The error due to the temperature effects (variations in the temperature of the comparator resistance coil and those of the resistance being compared due to surrounding conditions and the heating by the current running through them) has a random nature. Its value amounts to 0.00001 to 0.00005% if the loading of the resistances being compared does not exceed 0.05 w.

7. The errors due to the personal factor, the appearance of variable thermal emfs and other change effects are also of a random nature. It would appear that their values does not exceed 0.00001%.

In testing-out the bridge-comparator some 2000 resistance comparisons were made. In order to determine the distortion of comparison measurements by random errors the same resistor was measured several times and a series of measurements was obtained which contained 25 independent identical values.

The most probable error amounts to: 0.00001%-0.00005% for the comparison of resistors with nominal values of 0.1 to 1000 ohms; to 0.00005-0.0001% when comparing resistors of nominal values of 0.01, 0.001, 10,000 and 100,000 ohms; and to 0.0001-0.0005% in measuring resistors which are not equal to $10^{\pm k}$ ohms) with $\underline{k}$ being an integer) in the range of 0.001-100,000 ohms.

SUMMARY

The bridge-comparator raises the productivity 5-6-fold when measuring standard and reference resistors as compared with the productivity of measuring equipments which were used to date. Since the comparator does not use mercury contacts the labor conditions in handling it are improved.

The use of the comparator provides an average improvement of one order of accuracy in comparing resistors in the range of 0.001 to 100,000 ohms.

On the basis of the positive test results the bridge-comparator has been recommended for use in the Institutes of the Committee of Standards, Measures, and Measuring Instruments and the Metrological Institute of the Chinese People's Republic.

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CONTROLLED PHASE-SENSITIVE CIRCUITS WITH HEATED RESISTORS

V. S. Popov

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Basic elements of controlled phase-sensitive circuits (phase discriminators) consists of either dry or vibrating rectifiers, electronic or ionic tubes.

The Institute of Experimental Metrology of the Academy of Sciences USSR developed controlled phase-sensitive circuits on a new basis, that of heated resistors.

The characteristic of metallic heated resistors depends on the temperature coefficient of the heater resistance.

Tests of a number of unevacuated heated resistors showed that the relation of the resistance of the metal sensing element to the voltage across the heater with a large temperature coefficient can be expressed by the equation

$$R = c + c_1 U, \tag{1}$$

where R is the resistance of the sensitive element; c and c_1 – constants depending on the construction of the heated resistor.

Above relation can be obtained for metal heated resistors with platinum, tungsten, nickel, or copper heaters.

The best from the practical aspect is the platinum heater, which is stable and does not oxidize.

Figure 1 shows the clearly linear section of the heated resistor characteristic with a platinum heater 10 μ in diameter in a thin glass insulating tube over which the sensitive element consisting of a platinum 5 μ wire is wound in the shape of a helix.

Let us now examine the principle of operation of a phase discriminator with a heated resistor working on the linear part of its characteristic (Fig. 2).

The voltage applied to the heater of one of the resistors is equal to

$$\dot{U}_{н1} = \dot{U}_1 + \dot{U}_2.$$

and that applied to the other

$$\dot{U}_{н2} = \dot{U}_1 - \dot{U}_2.$$

For the effective values of these voltages we shall obtain respectively

$$U_{н1} = \sqrt{U_1^2 + 2U_1U_2\cos\varphi + U_2^2}\ .$$
$$U_{н2} = \sqrt{U_1^2 - 2U_1U_2\cos\varphi + U_2^2}$$

From the above and (1) the helical resistors will be, respectively,

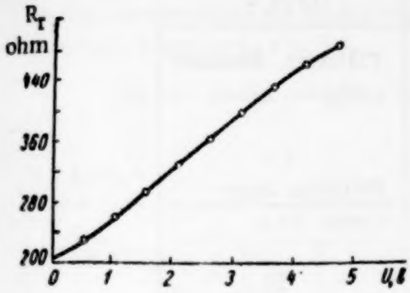

Fig. 1.

$$R_1 = c + c_1 U_{H1} = c + c_1\sqrt{U_1^2 + 2U_1U_2\cos\varphi + U_2^2}\ ,$$
$$R_2 = c + c_1 U_{H2} = c + c_1\sqrt{U_1^2 - 2U_1U_2\cos\varphi + U_2^2}\ .$$

If the parameters of the circuit are selected in such a manner that inequality $U_1 \gg U_2$ holds, the difference of the sensitive elements will be

$$R_1 - R_2 \simeq 2c_1U_2\cos\varphi, \qquad (2)$$

i.e., the difference of the helical resistors is directly proportional to $U_2 \cos\varphi$ independently of the voltage U_1. The difference of resistance R_1-R_2 can be measured on a balanced or comparator bridge.

Balanced bridge method. An equal ratio bridge is balanced manually or automatically by a variable resistance R_3. For the recording of the readings it is sufficient to connect the sensitive elements of the resistors to the two adjacent arms of an automatically balanced recording bridge.

Comparator bridge method. The voltage in the diagonal of an unbalanced bridge is equal to:

$$U_g = I_gR_g = R_g\frac{I_{ax}R\,(R_1 - R_2)}{R_g\,(R_1 + R_2 + 2R)\ + 2R\,(R_1 + R_2)}\ , \qquad (3)$$

where

$$\frac{R_g\ R}{R_g\ (R_1 + R_2 + 2R) + 2R\cdot(R_1 + R_2)} \simeq c' = \text{const};$$

I_{ax} is the auxiliary current feeding the bridge.

According to (2) the voltage in the bridge diagonal will now be proportional to the product of three quantities $I_{ax}U_2\cos\varphi$. This relation provides new possibilities in the application of controlled phase-sensitive circuits. If the bridge whose arms consist of the heated resistors helical windings is fed with a voltage proportional to the measured voltage, the output voltage of the bridge will be proportional to the measured power. When the sign of $\cos\varphi$ changes, the sign or phase of the output voltage will also change.

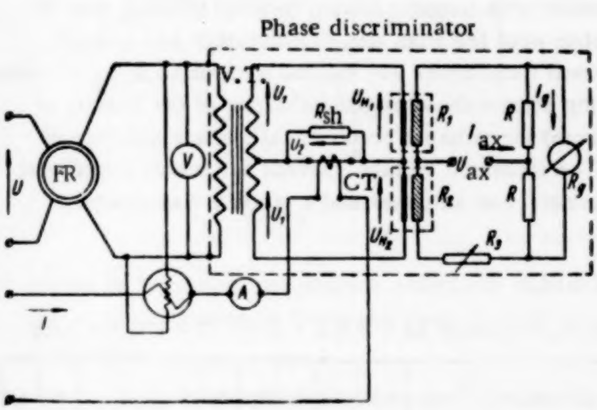

Fig. 2.

In deriving (2) it was assumed that the resistor constants c and c_1 are equal.

It is easy to equalize constants c of the two heated resistors by means of a resistor connected in series with the appropriate spiral winding of the heated resistor.

The value of constant c_1 can be adjusted (decreased) by means of a linear resistor connected in series with the heater. The additional resistor should be such that with a variable voltage and a constant current and power factor the difference in resistance $R_1 - R_2$ remains constant. Thus, the equality of constants c_1 will be ensured.

Since the internal resistances of the voltage sources U_1 and U_2 are not equal to zero, a similar result can be obtained by replacing the building-out resistance with a shunt. The characteristics of the phase-sensitive circuit will be the same in either case.

TABLE 1

	Type A	Type B	Type C
Heater	Tungsten, diameter, 10 μ	Platinum diameter, 10 μ	Platinum, diameter, 50 μ
Heater resistance at 20°C, ohms	10	20	1.0
Helix	Tungsten, diameter, 10 μ	Platinum diameter, 5 μ	Platinum diameter, 24 μ
Resistance of the helix at 20°C, ohms	30	200	15
Maximum operating temperature of the heated resistor, °C	250	550	550
Time constant, sec	0.10	0.04	0.80

Models of a phase discriminator and a wattmeter, power converter with tungsten, and platinum heater resistor were made in the Institute of Experimental Metrology of the Academy of Sciences, USSR.

Unevacuated heated resistors of three types were tested. Each heated resistor consisted of a heater in an insulated tube of molybdenum glass and a helical sensitive element wound over the tube. The external diameter of the insulated tube was 2-2.5 times greater than that of the heater.

In order to decrease the effect of the ambient temperature on the heated resistors, they were mounted in pairs in bulbs with a brass jacket intended for the mechanical and air current protection of the resistors.

With changes in the ambient temperature the temperatures of the helical windings, which were mounted in the same bulb, changed approximately by the same amount, and the difference of their resistances remained unchanged.

Table 1 gives the basic technical and design characteristics of the heated resistors.

At temperatures above 250-300°C, tungsten oxidizes to a considerable extent in air; however, the type A heated resistors withstand short overloads up to 400-450°C. At temperatures above 550°C the glass insulating tube becomes soft, thus damaging the B and C type resistors.

Figure 2 shows a circuit for testing phase discriminators with tungsten heated resistors working over the linear part of their characteristic. The heaters of the resistors were fed from step-down voltage and current instrument transformers. The secondary winding of the current transformer was shunted by resistance R_{sh} = 1 ohm in order to ensure a constant voltage at its secondary winding despite the changed resistance of the heaters in operation. At the nominal voltage (100 v) and current (5 amp) the voltages across the secondary windings of the transformers were $U_1 \simeq 2.0$v and $U_2 \simeq 0.5$v (Fig. 2). The measured voltage, current and power factor were checked during measurement by means of a grade 0.5 voltmeter and ammeter, and a grade 0.2 wattmeter.

TABLE 2

R_1-R_2 = F(I) for U = 100 v = const, $\cos\varphi$ = 1.0 = const

I, amp	0	0,5	1.0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0
R_1 R_2, ohm	0,00	1,25	2,50	3,80	5,05	6,30	7,50	8,80	10,05	11,30	12,50

TABLE 3

R_1-R_2 = F($\cos\varphi$) for I = 5 a = const, U = 100 v = const

$\cos\varphi$	1,0	0,9	0,8	0,7	0,6	0,5	0,4	0,3	0,2	0,1	0,0
$R_1 - R_2$, ohm	12.50	11,20	9,88	8,60	7,33	6,10	4,85	3,62	2,40	1,20	0,0

For the purpose of making the characteristics of the heated resistors symmetrical, resistor R_1' was connected in series with the helical winding R_1, and resistor R_4 in series with the heater of the same heated resistor (these

resistors are not shown in Fig. 2). After balancing resistor R_1' was set at 1.1 ohms and R_4 at 0.8 ohms.

The helical windings of the heated resistors were connected as two adjacent arms of a single bridge; during measurements the bridge was balanced by means of resistance R_3. The ratio arms of the bridge were, therefore, equal to $R_3 = R_1 - R_2$.

The test results are given in Tables 2, 3, and 4.

TABLE 4

U, V	I=5,0 amp					I=2,5 amp					I=0				
	80	90	100	110	120	80	90	100	110	120	80	90	100	110	120
R_1-R_2, ohm	12,40	12,50	12,55	12,55	12,50	6,23	6,28	6,30	6,28	6,23	0,10	0,05	0,00	−0,05	−0,10

It will be seen from Table 2 that for a constant voltage and power factor the difference in resistors R_1-R_2 is directly proportional to the measured current. The maximum referred error due to nonlinearity does not exceed 0.4%.

It will be seen from Table 3 that the relationship R_1-R_2 = F(cosφ) for I = const, U = const, deviates slightly from linearity with the maximum deviations occurring at $\cos\varphi = 0.6$ and mounting to 1.4%. This is not a random error. In fact expression (2) holds if $U_1 >> U_2$. If the difference between U_1 and U_2 is small, higher order terms should be taken into account when deriving (2). Thus (2) will take the form

$$R_1 - R_2 \simeq 2c_1 U_2 \cos\varphi \left[1 - 0.5\,(1-\cos^2\varphi)\, \frac{U_2^2}{U_1^2} \right].$$

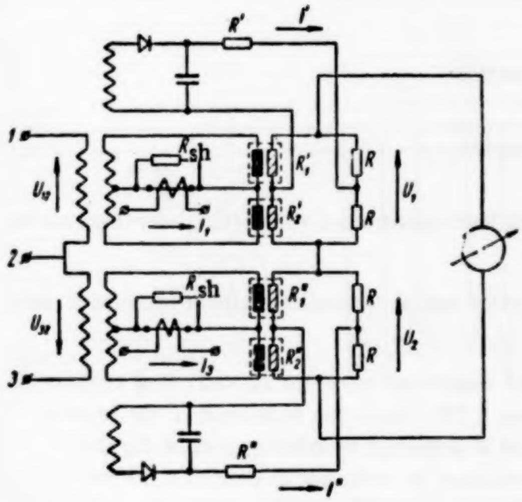

Fig. 3.

Taking into account that in this instance $U_1 \simeq 4U_2$, it can be easily seen that the error due to cosφ is caused by the measuring method. It can be greatly reduced by decreasing U_2 or increasing U_1. In decreasing U_2, sensitivity drops, however, and a large increase in U_1 is not permissible, owing to the shifting of the working range to a nonlinear part of the resistance characteristics.

It follows from Table 4 that variations of U_2 by ±10% from the nominal value for cosφ = const. and I = const. produce a referred error not exceeding 0.4% and for voltage variations of ±20% an error of 1.2%.

For nominal values of current and voltage and cosφ=1.0 a reduction in the auxiliary current feeding the bridge from 13 ma to 1 ma does not produce additional variations in the difference of the helical winding resistances. When the auxiliary current is increased from 13 to 20 ma the difference of the helical winding resistances increases by 0.06 ohms.

Tests of the phase discriminator type B with a platinum heater provided similar results. Owing to the high resistance of the platinum helical windings the sensitivity of the phase discriminator could be raised almost 6-fold, thus providing a decrease in the U_2 voltage to half its former value, i.e., made it possible greatly to increase the accuracy of the discriminator with a changing power factor. Owing to the use of very thin platinum wire, however, and the low mechanical strength of platinum, type B heaters are considerably less shockproof than the tungsten ones.

When operating speeds of the order of 3-4 sec meet the set requirements, the best results are obtained from type C platinum heated resistors, which possess considerably stability in overloading and a high mechanical strength.

The basic advantages of a phase discriminator with heated resistors as compared with a discriminator using diodes are the following: 1) It is possible to obtain at the output of a phase discriminator with heated resistors, in addition to the resistance variation, a dc or ac voltage of a high or low frequency (depending on the type of auxiliary supply used); 2) the voltage and current instrument transformers are not loaded by a dc component; 3) the measuring and input circuits have no electrical contact; 4) the main elements of the phase discriminator, the heated resistors possess, contrary to rectifier, a high stability.

It is also possible to use in phase discriminators thermal transducers with platinum heaters instead of the heated resistors. The difference in the thermocouple emf in this instance will be directly proportional to the value of $U_2 \cos\varphi$.

$$E_1 - E_2 = c\, U_2 \cos\varphi.$$

Figure 3 shows a schematic of a three-phase wattmeter-converter with heated resistors. It consists of two single-phase elements connected as a two wattmeter measuring circuit. The measuring bridge of each unit is fed from a special winding of the corresponding voltage transformer through a DGTs type rectifier.

The voltage in the measuring diagonal of the bridge of one of the units is equal according to (2) and (3) to

$$U_1 = I' c' (R_1' - R_2') = K U_{12} I_1 \cos (\widehat{U_{12} I_1}).$$

where K = const.

The voltage in the bridge diagonal of the other unit amounts to

$$U_2 = I'' c' (R_1'' - R_2'') = K U_{32} I_3 \cos (\widehat{U_{32} I_3}).$$

The sum of voltages U_1 and U_2 measured on a moving-coil instrument or an automatic potentiometer is equal to the required power of the three-phase circuit.

The summation constant K can be controlled in either unit by means of auxiliary linear resistors R' and R".

The basic error of the three-phase wattmeter is 0.7%. The additional error due to variations of the measured voltage by ±10% from its nominal value does not exceed 0.5%. Since the resistance of the heaters depends on temperature, temperature compensation is required and is achieved by making part of the shunt resistance R_{sh} from copper. Thus the temperature error of the wattmeter is made not to exceed 0.4% for ambient temperature changes of ±10%.

By its accuracy this three-phase wattmeter, which consists of a static converter and a moving-coil instrument, corresponds to an instrument of grade 1.5. The nominal output voltage of the converter amounts to 150 mv.

The three-phase wattmeter-converter is used as transmitter in the Institute's remote-measuring system. The static converter in conjunction with an automatic potentiometer can also be used for measuring, recording and controlling power.

The basic advantage of the wattmeter-converter as compared with the existing types of power converters with heated resistors consists in the absence of the auxiliary stabilized source of supplies [1].

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MEASURING THE CAPACITANCE OF CABLE CIRCUITS UNDER THE OPERATING VOLTAGE

G. V. Mindeli

Translated from Izmeritel'naya Tekhnika, No. 4, April, 1960

Methods for measuring insulation impedance with its real and imaginary components on cables and associated equipment in the absence of the working voltage are fairly well known and discussed in literature. Methods of measuring insulation impedance (the real component and capacitance) of a supply network under the working voltage are of great interest from the operational point of view.

For measuring the insulation resistance of supply networks with respect to earth under operating conditions, there exist several devices which are widely used in practice (the RUV designed by P. M. Leibov, the deviation meter and AKI instrument designed by N. V. Alekhnovich, meggers and insulation checking devices made by the Siemens Company, the insulation checking device designed by Shafranek, etc.).

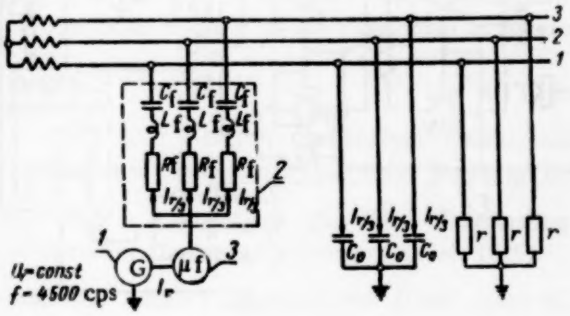

Fig. 1.

The existing methods of measuring capacitance under the working voltage are indirect, require intermediate measurements and subsequent calculations, and as a rule interfere with the normal operation of the mains [1, 2].

We describe a method and a device which we propose for direct measurement of the capacity of mains under the working voltage [3]. The schematic which explains the method is shown in Fig. 1. The circuit uses a high frequency generator (4500 cps) with a constant voltage at the output, one of whose terminals is connected to a three-phase (or single-phase) mains by means of a tuned filter 2 and the other terminal is grounded, through a rectifier circuit using DGTs-24 diodes and a moving-coil instrument 3 which is calibrated in microfarads. The filter induction coils have 3200 turns each and are wound on nonmagnetic toroidal formers (made of plexiglas). The filters are tuned to the generator frequency and hence present to the generator a purely resistive impedance.

Since the generator load consists of the constant resistance of the coil windings and the variable mains capacity, the sensitivity of the circuit ot generator current I_g, variations will be large when the coil resistance is small. The insulation resistance r does not affect appreciably the results since for a current of 4500 cps $x_c << r$. On the basis of this consideration the coil should be wound with litz wire in order to reduce its resistance at high frequencies. On the other hand the filter must not reduce the insulation of the mains with respect to ground, i.e., the filter impedance at 50 cps must be as high as possible, and hence the value of the filter capacitors C_f as small as possible. In order to provide a small capacity and resonance at the required frequency, the inductance of the coil must be large. The latter circumstance prevents the use of litz wire, which would make the coils too large.

In the model of the instrument the coils were wound with PV-2, 0.49 mm wire, and the filter ac resistance amounted to 13.5 ohms.

The circuit (Fig. 1) operates as follows. The high-frequency current flows through the tuned circuit, the capacity of the cable to ground, and through instrument 3 back to the generator. The value of the current is controlled by the cable capacitance only, since the remaining parameters of the circuit are constant. Thus, the scale of the measuring instrument can be calibrated in μf. The instrument range is from 0.2 to 6 μf.

Figure 2 represents the electrical circuit of the instrument. The generator works on type P11 junction transistors. A quartz crystal with a natural resonance frequency of 1500 cps is used for frequency stabilization.

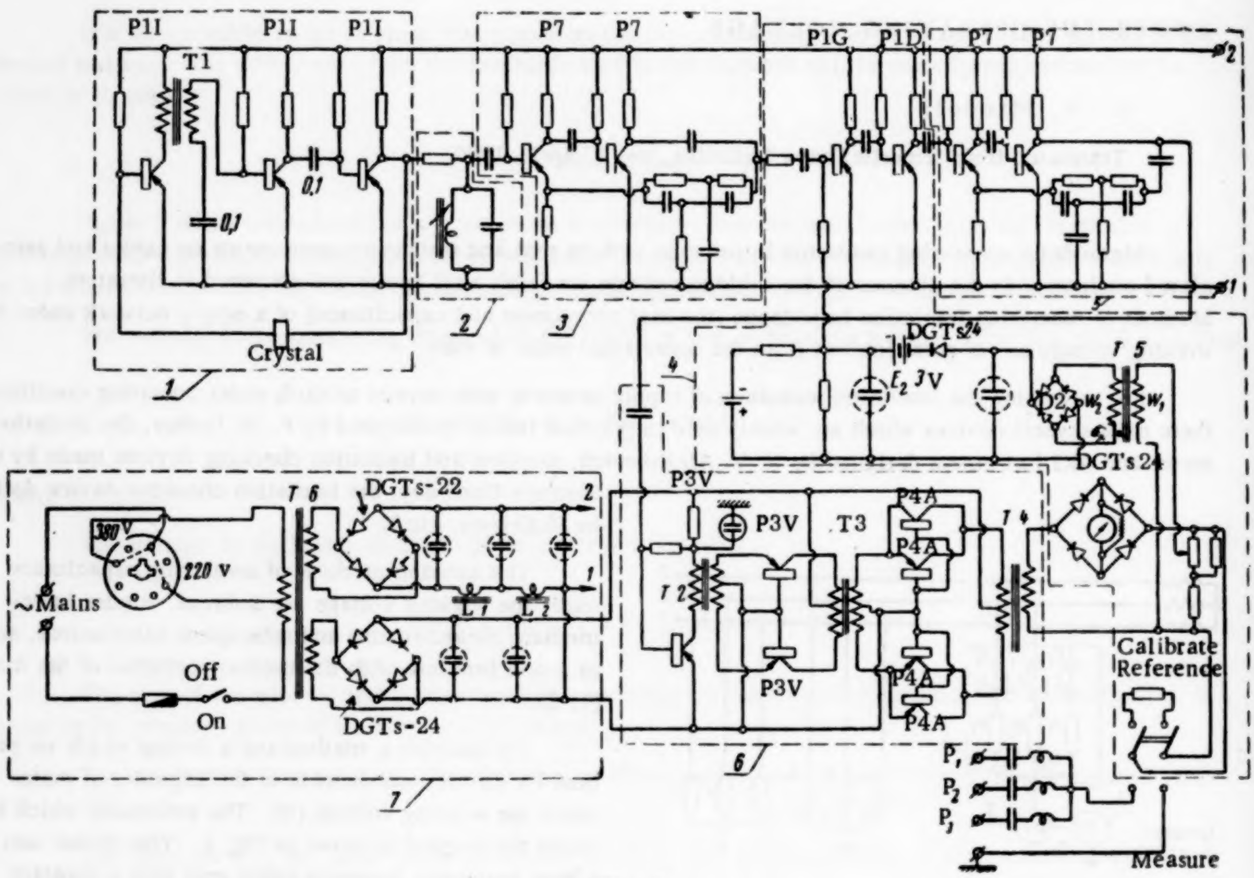

Fig. 2.

The circuit is supplied from a 7 v power pack. The high gain of the amplifiers (50000) provides the possibility of obtaining at the generator output a rectangular instead of a sinusoidal waveform, thus easily providing the third harmonic.

Filter 2 consists of a parallel circuit tuned to 4500 cps. The voltage from filter 2 is fed to filter 3 which consists of a two stage P7 transistor amplifier with a twin T negative feedback circuit.

From filter 3 the voltage is fed to the automatic gain control unit 4 (AGC) intended for stabilizing the amplitude of the output generator voltage against both changes and oscillations in the supply voltage.

The AGC utilizes the property of transistors to vary their gain with changes in the base biasing voltage, thus providing a constant output voltage with an accuracy of 0.5% for mains voltage variations of ± 15-20%. With changes in the load of the generator from 20 to 150 ohms, its output voltage varies by 1%, this effect is, however, accounted for in the calibration of the scale.

The absolute value of the generator output voltage is set by means of the variable resistor of 1 kilohm.

Filter 5, which is tuned to 4500 cps, consists of a circuit similar to that of filter 3 and is intended for improving the voltage waveform at the AGC unit output. The filter output voltage is fed to the power amplifier 6 which works with transistors P3V and P4A. The first stage of the amplifier operates as a voltage amplifier and phase splitter. The penultimate stage consists of two P3V transistors connected in a common push-pull circuit in order to reduce distortions.

The output stage consists of four P4A transistors connected in a parallel push-pull circuit. The powerful output stage provides a sinusoidal voltage without distortions over the whole range of loading.

Unit 7 is a power pack which supplies the generator and operates from 220 or 380 v, 50 cps mains.

It should be noted that the instrument will measure accurately at a given frequency only if the length of the measured cable is considerably smaller than a quarter of a wavelength.

For a line without losses the phase velocity of wave propagation is expressed by the formula

$$v = \frac{C}{\sqrt{\epsilon\mu}},$$

where C is the velocity of light, ϵ and μ are, respectively, the permittivity and permeability of the dielectric surrounding the conductor.

For open wire circuits $\epsilon \simeq 1$ and $\mu \simeq 1$, and, hence, the speed of wave propagation v is practically equal to the speed of light.

For cables, ϵ is between 4 and 5. Hence, the speed of wave propagation in cables can be $1/2$ to $2/5$ that of light in free space, i.e., some 120,000 to 150,000 km/sec [4].

The wave length λ at a frequency of 4500 cps will be in a cable of the order of 30000 m, i.e., quarter of a wavelength will be approximately 7.5 km. Hence the instrument will operate without distortions over cable lengths of the order of 2-2.5 km without taking into account branch circuits. In practice the length of low voltage cable mains from the transformer to the most remote consumer seldom exceeds 800-1000m.

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A MACHINE FOR TRANSCRIBING SCALES WHEN REPAIRING ELECTRICAL MEASURING INSTRUMENTS

A. I. Rozhkov

Translated from Izmeritel'naya Tekhnika, No. 4, p. 42, April, 1960

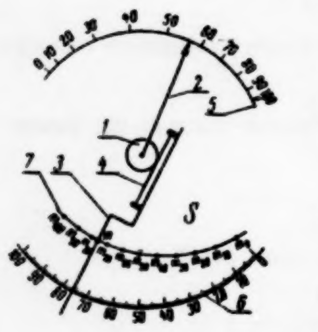
The repair of electrical measuring instruments often involves their recalibration and the rewriting of their scales, both labor-consuming processes which are normally done by hand. These operations obviously require considerable experience and it is difficult to attain high quality in their execution.

The machines used for plotting the scales of electrical measuring instruments are very complicated, unsuitable for wide distribution, and only provide equally spaced graduations between given limits.

Such graduation does not meet the calibration law requirements of many measuring instruments.

The author has developed a machine which provides the plotting of intermediate graduations between given limits according to a given calibration law along the whole length of the scale [1].

Pulley 1 firmly fixed to pointer 2 can be freely rotated about its axis and is connected to a guiding rod 3 by means of flexible cable 4, which is wound around the pulley. Owing to this connection, pointer 2 can rotate about its axis due to two movements of guiding rod 3, i.e., due to its longitudinal movement, and its rotation about the pulley axis.



In order to divide scale 5 between the previously plotted datum points (0, 10, 20 . . .) the guiding rod is placed on calibration 0 of the uniformly divided scale 6, and pointer 2 is brought to graduation 0 on scale 5 by means of the longitudinal movement of rod 3. Next point m of the guiding rod is projected onto the surface S.

Similar projections are plotted for graduations 10, 20, etc. The line connecting the projections of point m on surface S provides a calibration curve 7 for scale 5.

The division of scale 5 between the datum points is carried out by moving the guiding rod 3 along the evenly divided scale 6 in such a manner that point m on the rod slides along the calibration line 7.

A machine constructed according to this schematic has been in operation for about one year with satisfactory results: the time for copying scales has been cut down, and the quality of the repaired instruments' scales has considerably improved.

The machine can be made in mechanical workshops with an average equipment.

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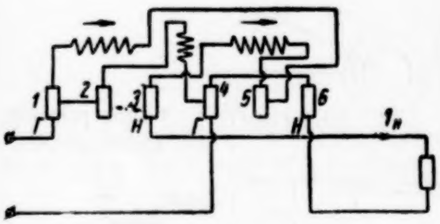
A CHANGE IN THE INTERNAL CONNECTIONS OF SINGLE-PHASE ELECTRICITY METERS TYPE M AND R-1

M. I. Roman

Translated from Izmeritel'naya Tekhnika, No. 4, p 43, April, 1960

In the single-phase 220 v, 5 amp electricity meters type M and R-1, which are now being used, the magnetic flux of the current circuit is equal to the sum of the fluxes produced by two equal current windings, which are connected to each of the supply conductors.

In 380/220 v mains with a grounded neutral point the customer is able to short the winding connected in series with the neutral conductor, by grounding it at the load end or else he can simply disconnect it after grounding.



In both cases the magnetic flux in the current circuit is decreased. The torque of the meter is decreased accordingly and the meter reading reduced.

In order to eliminate the possibility of reduced readings of these meters it is necessary to make the alterations shown in the accompanying figure, a diagram of the internal connections.

The alterations in the internal connection of the electricity meters M and R-1 can be made when they are sent for repairs.

DETERMINING THE SHORT-TERM INSTABILITY OF QUARTZ OSCILLATOR FREQUENCIES

F. F. Evstaf'ev

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The Khar'kov State Institute of Measures and Measuring Instruments has made an instrument for measuring the beat periods of crystal oscillators, which consists of a trigger controlled by a discriminator [1, 2] and, according to the required accuracy of measurement, either a printing chronograph or an oscilloscope with circular scanning. The instrument is supplied from stabilized ac mains. The schematic of the instrument is shown in Fig. 1.

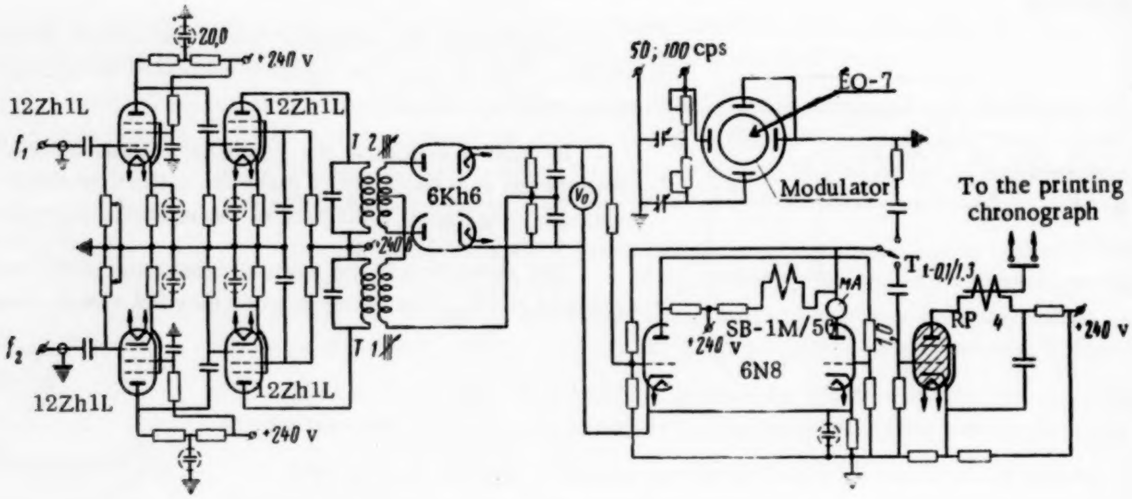

Fig. 1.

The oscillator voltages of frequencies f_1 and f_2 are amplified by amplifiers working with 12Zh1L tubes up to a certain level and then fed through transformers T1 and T2 to the phase discriminator, which uses a 6Kh6 tube. The secondary winding of transformer T2 is divided into two equal parts. The voltages across the secondary windings of transformer T1 and both halves of transformer T2 are supposed to be the same and equal to E. The rectified voltages across the diode load resistors are E_{01} and E_{02}. The voltage at the output of the discriminator is equal to the difference between E_{01} and E_{02} and varies with the oscillator frequency period.

This voltage is equal to zero for a phase difference between the voltage vectors AD and AB, AB and AD_1 equal to $\pi/2$ and $3\pi/2$; it reaches a maximum of 2E and −2E for a phase difference of 0 and π respectively (Fig. 2). A center zero voltmeter V_0 is connected to the output of the discriminator. It will be seen from the graph (Fig. 3) that the relation of the discriminator output voltage to the phase difference is almost linear over the greater part of the curve to both sides of $\pi/2$. The sensitivity of the discriminator for an actual amplitude of 45 v is about 30 v/rad.

The discriminator output is connected through a 200 kilohm resistor to the trigger input which works with a 6N8 tube [3]. The negative bias on the grid of the valve is such that the trigger operates when the discriminator output voltage is zero. The instant of trigger operation is, therefore, independent of the value of the voltages fed to the input of the instrument and is determined only by their phase difference. The pulse produced by the trigger, is transmitted through a differentiating network RC either to the terminal of the ÉO-7 oscilloscope beam-intensity electrode "modulator" for marking the triggering time on the circular scanning display, or to the input of thyratron TG1-0.1/1.3 which by means of relay RP4 operates the printing chronograph with an error of 2 msec.

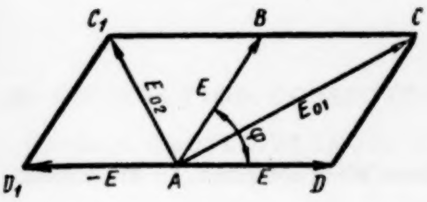

Fig. 2.

A counter of the SB-1M/50 type registers whole numbers of beats.

In order to obtain circular scanning, the oscilloscope is supplied with 50, 100, and 1000 cps. The transparent scale screen of the oscilloscope has 100 graduations marked on it. The value of each graduation is $2 \cdot 10^{-4}$, $1 \cdot 10^{-4}$, or $1 \cdot 10^{-5}$ sec, according to the sweep frequency used.

The phase resolution of the instrument was measured by means of a bridge-type phase shifter (Fig. 4) whose phase rotation was equal to [2]

$$\varphi = -\tan^{-1}\frac{2\omega CR}{(\omega CR)^2-1}.$$

And the phase increment is

$$\Delta\varphi = \frac{2\omega C\Delta R}{(\omega CR)^2+1}.$$

Since the trigger operates at phase differences of $\pi/2$ set up by the phase shifter, $\omega CR = 1$ and for $C = 250$ $\mu\mu f$ and $\omega = 2\pi f = 2\pi 6 \cdot 10^4$, we obtain

$$\Delta\varphi = 0.9 \cdot 10^{-4}\,\Delta R \text{ rad} \tag{1}$$

The inputs of the instrument were fed directly and through a phase shifter with a phase shift of about $\pi/2$ from a 60 kc reference crystal oscillator. During the repeated measurements (some 240 were made) the trigger operated at different values of the variable resistor in the phase-shifter bridge circuit. The phase shift was

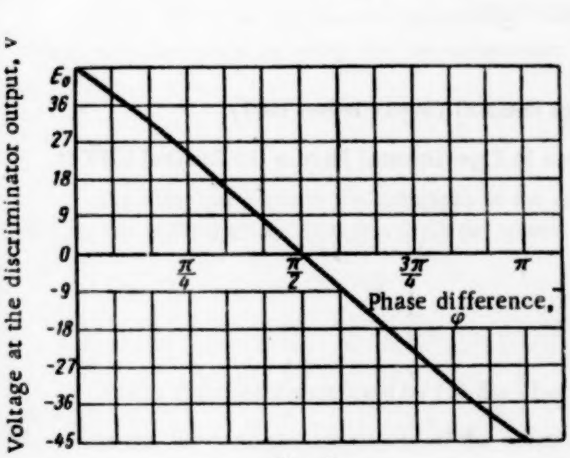

Fig. 3.

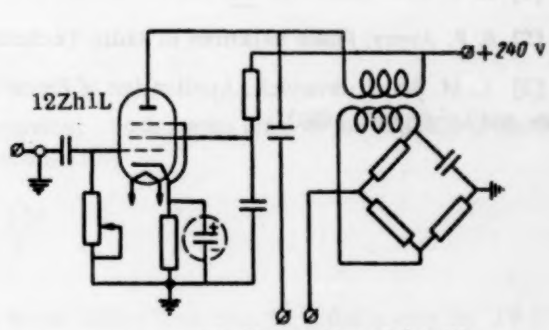

Fig. 4.

measured every 15 sec. It was established that the root-mean-square deviation of the phase shifter bridge reading at every 15 sec intervals was equal to $\Delta R = 1.05$ ohms and for minute intervals $\Delta R = 1.50$ ohms.

From (1) we obtain the phase shift for each 15 sec interval as: $\Delta\varphi = 1.0 \cdot 10^{-4}$ rad and for intervals of a minute $\Delta\varphi = 1.4 \cdot 10^{-4}$ rad.

The relative error in measuring frequency due to the error in determining the phase difference $\Delta\varphi$ is equal to

$$\frac{\Delta f}{f} = \frac{\Delta\varphi}{2\pi f n T} = \frac{\Delta\varphi}{2\pi f t}. \tag{2}$$

where T is the beat period; t – the duration of n beat periods of the oscillators being compared, f – the nominal value of the frequency of the compared oscillators.

From (2) we obtain the phase discrimination of the instrument, in terms of the relative variation of frequency for 15 sec intervals $\Delta f/f = 2 \cdot 10^{-11}$ and for minute intervals $\Delta f/f = 6 \cdot 10^{-12}$.

The accuracy of phase measurements depends on the constancy of the voltages feeding the instrument. Thus, the relation of the phase of the 60 kc voltage to the supplies of the oscillator was determined by means of the same phase shifter.

Variations of the anode and heater voltages by $\pm 10\%$ produced a phase difference in the voltages of $\pm 3 \cdot 10^{-3}$ rad. From (2) we find that a phase difference of $3 \cdot 10^{-3}$ rad corresponds to a relative variation of the frequency for minute intervals of $1.3 \cdot 10^{-10}$. In fact the stabilized anode and heater voltages did not vary by more than $\pm 0.3\%$, which corresponds to a relative frequency variation for minute intervals of $\pm 4 \cdot 10^{-12}$.

SUMMARY

The measurement results show that phase shift in the instrument depends but very little on the voltages of the frequencies being compared or the sources of supply, thus providing the possibility of using the above instrument for comparing frequencies of crystal oscillators continuously throughout the day and night with great precision.

This instrument in conjunction with the phase shifter can also be used as a phase meter for measuring phase shift with great precision. Thus, the error in measuring a phase difference at 60 kc does not exceed $1 \cdot 10^{-4}$ rad.

If required it is possible to raise the precision of frequency deviation measurements by either increasing the sensitivity of the discriminators by means of larger input voltages to the discriminator, or by multiplying the frequencies under comparison.

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A DIFFRACTION CORRECTION FOR A RADIO-INTERFEROMETER WITH A CLOSED BRANCH

G. S. Simkin

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In the last 10-15 years, radio-interferometers in the centimeter and millimeter bands are being more and more widely applied for measurements of various types: of wavelengths, speed of light, long distances, and a number of other quantities [1, 2, 3, and 4].

Not all the types of double beam and multibeam interferometers at present in use are, however, suitable for precise measurements of the above quantities.

Radio-interferometers, contrary to optical interferometers, have one important characteristic which must be taken into account in their design and use.

In optical interferometers flat waves* can be used which remain almost unchanged at large distances from the source, but in radio-interferometers it is practically impossible to produce flat waves over relatively large distances. In this connection the disposition of various units in radio- interferometers must differ from that adopted in optical interferometers.

Owing to diffraction, flat waves change with distance becoming converted to spherical or cylindrical waves.

It is possible to show by means of Fresnel integrals that the variations of the flat wave with distance can be represented by the following expression:

$$\gamma = \sqrt{10\lambda R}, \qquad (1)$$

where λ is the wavelength and R the distance from the source of radiations.

If the radiation aperture be denoted by D (diameter of the lens,, the diaphragm or the dimensions of the horn), the distance R at which flat waves become cylindrical or spherical is

$$R = \frac{D^2}{40\lambda}. \qquad (2)$$

The simplest wave is the spherical or the quasi-spherical. Such waves arise in the far zone (Fraunhofer diffraction region) whose distance from the source is determined by

$$R_\partial = \frac{2D^2}{\lambda}. \qquad (3)$$

At the distance determined by (3) the directivity factor differs from that for infinity only by 1% [5].

In the far zone the amplitude of the electromagnetic field is determined at any point of the plane parallel to the radiation plane by the radiation pattern, and the field characteristics are relatively easy to calculate. Moreover, the field amplitude at any point of the above plane in the far zone is determined only by the angle

*We understand here by the term of a flat wave, a wave whose points of equal phase lie in the same plane.

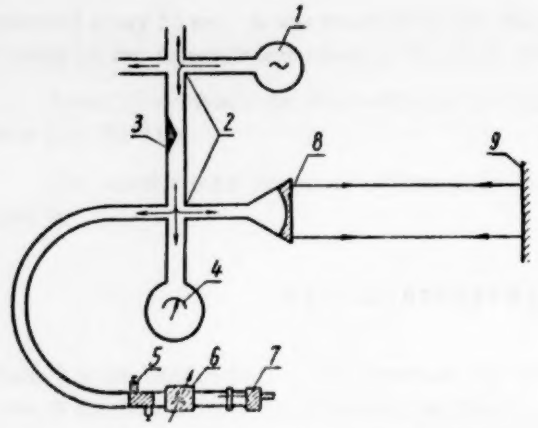


Fig. 1. Schematic of a radio-interferometer with a closed branch. 1) Stabilized ultrahigh frequency oscillator; 2) hybrid junctions; 3) attenuator; 4) detector and indicator; 5) matching transformer; 6) adjustable attenuator; 7) shorting plunger with a microscrew; 8) transmitting horn with a lens; 9) adjustable reflector.

made by the normal to the radiation surface with the direction to the given point, whereas in the near zone (Fresnel region) the field amplitude is determined by two parameters: the distance to the given point and the angle. Calculations show that the amplitude at a given point has a complex relationship to the distance.

The impossibility of using flat waves in radio-interferometers makes it necessary to use a correction for diffraction. The value of the diffraction correction is considerable and cannot be neglected in precise measurements made on the radio-interferometer.

The calculation of this correction when certain elements of the radio-interferometer are in the Fresnel region meets with considerable difficulty. The problem is simplified if the correction is calculated for the far zone. If however, the radio-interferometer is designed as a Michelson type interferometer with a reflecting semi-transparent mirror, great difficulties arise in calculating the correction.

The simplest radio-interferometer circuit consists of a double beam interferometer with one of its branches closed (Fig. 1), which was suggested by Fromme and used by him for measuring the velocity of light with great precision [6]. For such an interferometer, the diffraction correction can be calculated with an error of 6% in the value of the correction.

Below we give the calculation of the diffraction correction for a radio-interferometer with a closed branch.

Basic data. A pyramidal horn with a flat-convex dielectric lens placed inside it serves as a radiator. Thus the mouth of the horn consists of a flat rectangular opening.

The plane of the rectangular reflecting mirror is placed parallel to the plane of the opening. Let us use for the calculation of the diffraction correction a rectangular system of coordinates X, Y, and Z and let us place it in such a manner that the Z-axis passes through the middle of the horn mouth and the mirror. Let us also assume that in the mouth, field E is linearly polarized and in the direction of the Y-axis. Let the coordinates of a point lying in the plane of the horn opening be x_p, y_p, and 0 and the coordinates of point M, located on the mirror be x_m, y_m, and z.

Let us denote the field along the mouth of the horn by $f(x_p, y_p)$. Let the law of distribution of its amplitude be $A(x_p, y_p)$ and of the phase $\psi(x_p, y_p)$, then

$$f=(x_p, y_p)=A(x_p, y_p)\, e^{-ik\psi(x_p, y_p)}. \tag{4}$$

The reflecting mirror is placed in the far zone.

The problem of determining the diffraction correction amounts on the whole to the following. Knowing the distribution of the amplitudes and phases of the electromagnetic field in the mouth of the horn, it is necessary to find the lagging of various beams falling on the mirror, or the difference of phases for the nonaxial beams, which amounts to the same thing (since the wave incident to the mirror has a spherical front). Next the same problem has to be solved for the rays reflected from the mirror and falling on the horn. Then it is necessary to determine the total (integrated) value of phase differences at the point where the interference of the beams coming from the horn and the constant branch takes place.

It is at present impossible to provide a precise solution of this problem [5, 7, 8] in view of the difficulty of accounting for all the circumstances connected with the distribution of the field in the mouth of the horn, the difficulty of estimating the effect of the field radiated by the external surface of the horn and the effect of repeated reflections of the field from the horn and mirror, etc.

Experience and calculations show, however, that with the mouth of the horn dimensions greatly exceeding the wavelength used, the error in the calculated diffraction correction does not exceed 7% A more precise value of the diffraction correction may be obtained experimentally,as will be shown later.

For determining the difraction correction let us use Maxwell's equation, whose solution provides the following value for the E component of the electromagnetic field:

$$E_M = \frac{1}{4\pi} \int_S f(x_p, y_p) \frac{e^{-ikr}}{r} \left[\left(ik + \frac{1}{r} \right) \vec{n}\vec{r} + \right. \tag{5}$$

$$\left. + ik\vec{n}\vec{R} \right] dx_p dy_p,$$

where $f(x_p, y_p)$ is the field distribution in the mouth of the horn, $\underline{k}$ is the wave number ($k = 2\pi/\lambda$); $\underline{r}$ is the distance from any point of the mouth of the horn to point M on the mirror, $\vec{n}$ is the unit vector perpendicular to the equiphase surface of the field, $\vec{r}$ is the unit vector directed from any point in the mouth to point M on the mirror, and $\vec{R}$ is the unit vector in the direction from the origin of the reference system to point M.

Since the mirror is in the far zone, and owing to the presence of the lens which provides a flat wave in the mouth of the horn, it is possible to simplify (5) by neglecting in the round brackets term $1/r$ which is small compared with k; and by neglecting the variations of product $\vec{n} \cdot \vec{R}$ at the opening of the horn and replacing it by a constant $\vec{n} \cdot \vec{R} = \cos\Theta$. Finally it is possible to neglect,in integrating,the variations of $1/r$,outside the bracket, and to replace it by $1/R$.

The variations of $\underline{r}$ included in the phase multiplier e^{-ikr} must be taken into account. In a general case:

$$r = \left[(x_p - x_3)^2 + (y_p - y_3)^2 + z^2 \right]^{\frac{1}{2}}. \tag{6}$$

Since the field is concentrated in a narrow cone near the Z axis (the dimensions of the horn and the mirror are small), and considering that the field is being determined in the far zone, i.e.,

$$z \gg (x_p - x_3),$$

relationship (6) can be written in the following form:

$$r \simeq z + \frac{(x_p - x_3)^2}{2z} + \frac{(y_p - y_3)^2}{2z}. \tag{7}$$

It is possible to neglect terms above the second order.

Moreover let us assume that the horn radiates a flat wave whose equiphase surface is parallel to the plane of the horn mouth. In this instance the phase factor in (4) is equal to 1. Thus,

$$f(x_p, y_p) = A(x_p, y_p). \tag{8}$$

Taking into consideration the above assumptions, we obtain for expression (5)

$$E_M = \frac{ike^{-ikz}}{4\pi R} (1 + \cos\Theta) \int_S A(x_p, y_p)\, e^{-ik\left[\frac{(x_p - x_3)^2}{2z} + \frac{(y_p - y_3)^2}{2z} \right]} dx_p dy_p. \tag{9}$$

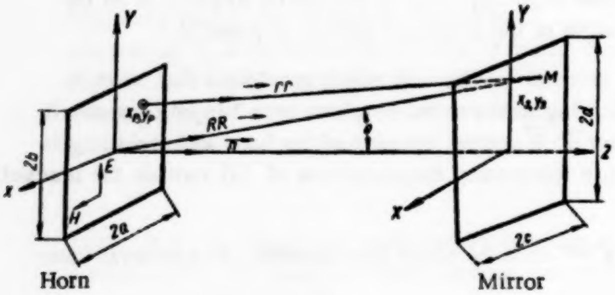
Since angle Θ is small (it does not exceed one degree, $\Theta \simeq D/R$), it is possible to assume with sufficient accuracy that $\cos\Theta = 1$ and

$$E_M = \frac{ike^{-ikz}}{2\pi R} \int_S A(x_p, y_p)\, e^{-ik\left[\frac{(x_p - x_3)^2}{2z} + \frac{(y_p - y_3)^2}{2z}\right]} dx_p dy_p. \tag{10}$$

For the determination of the diffraction correction it is necessary to establish the law of the vector amplitude distribution of field E (Fig. 2). It is known that this distribution along the X axis of a rectangular waveguide which feeds the horn has the form

$$E = E_0 \cos\frac{\pi x}{2a}. \tag{11}$$

The mouth of the horn will have a similar amplitude distribution. It is also known that if a flat-convex spherical lens is used, the electromagnetic flux becomes a little denser in its middle (Fig. 3.



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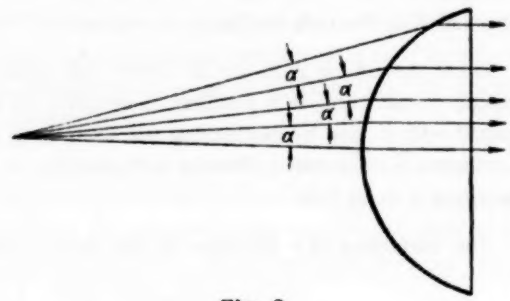

Fig. 3.

Calculations indicate [8] that the relation of the field intensity E at point P to the field intensity E_0 at the center of a flat-spherical lens can be represented by the expression

$$\frac{E_p}{E_0} = \sqrt{\frac{(n\cos\alpha - 1)^3}{(n-1)^2(n - \cos\alpha)}}, \tag{12}$$

where n is refractive index, and α is the angle of incidence at the lens of rays from a point source (Fig. 3).

Calculations show that the above effect of the lens affect but little the distribution of field amplitudes along the X axis determined from (11).

A much larger variation of amplitude occurs in the direction of the Y axis.

Let us note that the use of (12) for integrating purposes is rather complicated and is approximated with sufficient accuracy by a simpler relationship of the form

$$\frac{E_p}{E_0} \simeq \left[1 - \frac{ny^2}{2(n-1)f^2}\right]. \tag{13}$$

where n is the refractive index and f is the focal distance.

Calculations show that with a focal distance f = D or f = 2D and n = 1.5, the accuracy of approximation is better than 6%.

Taking into account the above considerations it is possible to express the field amplitude at the mouth of the the horn by the following relation:

$$A(x_p, y_p) = E_0 \cos\frac{\pi x}{2a}\left[1 - \frac{ny^2}{2(n-1)f^2}\right].$$

In order to determine the phase difference (degree of lag) for a given distance (R_1) of the mirror from the horn it is necessary to take the argument of the following six integrals:

$$\varphi_{R_1}=\arg\left[\frac{E_0 ike^{-ikz}}{2\pi R_1}\int_{-a}^{a}\int_{-b}^{b}\int_{-c}^{c}\int_{-d}^{d}\int_{-a}^{a}\int_{-b}^{b} e^{-ik\frac{(x_p-x_3)^2}{2z}}\times\right.$$

$$\times\cos\frac{\pi x}{2a}\, e^{-ik\frac{(y_p-y_3)^2}{2z}}\left(1-\frac{ny^2}{2(n-1)f^2}\right)\times \tag{15}$$

$$\left.\times e^{-ik\frac{(x_3-x_p)^2}{2z}}\, e^{-ik\frac{(y_3-y_p)^2}{2z}}\right] dx_p dy_p dx_3 dy_3 dx_p dy_p.$$

Elementary functions cannot be used with the above integrals, and it was therefore necessary to solve them by means of series.

The diffraction correction for two positions of the mirror (R_1 and R_2) with respect to the radiator can be determined from the following relation:

$$\delta=\frac{\lambda}{4\pi}(\varphi_{R_1}-\varphi_{R_2}), \tag{16}$$

where

$$\varphi_{R_1}=\tan^{-1}\frac{A_1'B_1''+A_1''B_1'}{A_1'A_1''-B_1'B_1''}, \tag{17}$$

$$\varphi_{R_2}=\tan^{-1}\frac{A_2'B_2''+A_2''B_2'}{A_2'A_2''-B_2'B_2''}. \tag{18}$$

Here

$$A_1'=1-\frac{1}{120}\left[\frac{\pi(a+c)^2}{\lambda R_1}\right]^2\frac{(a+c)^2}{ac}\alpha_2'+$$
$$+\frac{1}{4320}\left[\frac{\pi(a+c)^2}{\lambda R_1}\right]^4\frac{(a+c)^2}{ac}\alpha_4'; \tag{19}$$

$$B_1'=\frac{1}{24}\left[\frac{\pi(a+c)^2}{\lambda R_1}\right]^1\frac{(a+c)^2}{ac}\alpha_1'-$$
$$-\frac{1}{672}\left[\frac{\pi(a+c)^2}{\lambda R_1}\right]^3\frac{(a+c)^2}{ac}\alpha_3'+ \tag{20}$$
$$+\frac{1}{31680}\left[\frac{\pi(a+c)^2}{\lambda R_1}\right]^5\frac{(a+c)^2}{ac}\alpha_5';$$

$$A_1''=1-\frac{1}{90}\left[\frac{\pi(b+d)^2}{\lambda R_1}\right]^2\frac{(b+d)^2}{bd}\alpha_2''+$$
$$+\frac{1}{37800}\left[\frac{\pi(b+d)^2}{\lambda R_1}\right]^4\frac{(b+d)^2}{bd}\alpha_4''; \tag{21}$$

$$B_1^{\cdot} = \frac{1}{12}\left[\frac{\pi (b+d)^2}{\lambda R_1}\right]^1 \frac{(b+d)^2}{bd}\, \alpha_1^{\cdot} - \tag{22}$$

$$-\frac{11}{56000}\left[\frac{\pi (b+d)^2}{\lambda R_1}\right]^3 \frac{(b+d)^2}{bd}\, \alpha_3^{\cdot} + \frac{1}{31185}\left[\frac{\pi (b+d)^2}{\lambda R_1}\right]^5 \frac{(b+d)^2}{bd}\, \alpha_5^{\cdot}.$$

$A_2^{\cdot}$, $B_2^{\cdot}$, $A_2^{\cdot\cdot}$ and $B_2^{\cdot\cdot}$ are determined from the same formulas (19), (20), (21), (22), but in this case R_1 should be substituted by R_2.

Formulas determining the values of coefficients $\alpha_1^{\cdot}$, $\alpha_2^{\cdot}$ . . . $\alpha_1^{\cdot\cdot}$, $\alpha_2^{\cdot\cdot}$, $\alpha_3^{\cdot\cdot}$, . . . expressed in terms of the horn and mirror dimensions and the lens parameters are not given (they can be obtained from the Khar'kov State Institute of Measures and Measuring Instruments).

Formulas determining $A_1^{\cdot}$, $A_2^{\cdot}$, $B_1^{\cdot}$, $B_2^{\cdot}$, and $A_1^{\cdot\cdot}$, $A_2^{\cdot\cdot}$, $B_1^{\cdot\cdot}$, and $B_2^{\cdot\cdot}$ are approximate, and the diffraction correction error was evaluated for the case when $A_1^{\cdot}$, $B_1^{\cdot}$, $A_2^{\cdot}$, $B_2^{\cdot}$, etc., are expressed by three terms, i.e., when terms of the form M/λ^6R^6 and N/λ^7R^7 are neglected.

For the convenience of determining the error due to the above causes the evaluation was made for A_1 and B_1; moreover it was assumed that $\pi\alpha^2/\lambda R_1 = 0.5$. This value of $\pi\alpha^2/R_1$ corresponds to the position of the mirror at the boundary of the far zone.

It can be shown that the error of the diffraction correction $\Delta\delta/\delta$ expressed in terms of percentage can be represented by the relation

$$\frac{\Delta\delta}{\delta}\,\% < \frac{2\,(B_1'\alpha_6\Delta A_1' - A_1'\alpha_7\,\Delta B_1)\cdot 100}{(A_1'^2 + B_1'^2)\tan^{-1}\dfrac{2A_1'B_1'}{A_1'^2 - B_1'^2}}. \tag{23}$$

Calculation showed that $\Delta\delta/\delta < 1\%$.

Distance between the horn and the mirror, m	Diffraction corrections calculated by means of the formula given in this article, μ	Diffraction corrections obtained by Fromme, μ	Δ, %
6.5	174.0	163.8	6.3
9.0	84.7	79.9	6.0
12.0	46.0	43.2	6.5
16.0	24.8	23.4	6.0
21.5	13.7	12.9	6.2

The accuracy of evaluating diffraction corrections on the basis of their experimental determination was also checked. For this purpose corrections were calculated for the experimental data obtained by Fromme [2] in measuring the speed of light by means of a double-beam interferometer.

The table above compares the diffraction corrections obtained by Fromme and calculated by us.

It will be seen from the table that the discrepancy between them does not exceed 6.5%.

For especially precise measurements it may be necessary to determine the diffraction corrections with a greater accuracy than these formulas provide.

A further increase in the accuracy of determining the diffraction correction is achieved in the following manner.

In a given position R_1 of the reflector with respect to the horn, a half-wave sequence $n\lambda_e/2 = l_1$ is measured. Next, having placed the mirror at another distance $R_2 > R_1$, the same $n\lambda_e/2$ is measured again. In this instance the value of $n\lambda_e/2$ will differ from the one obtained in the first instance, i.e., $n\lambda_e/2 = l_2$. The diffraction corrections (δ_1 and δ_2) for l_1 and l_2 are calculated from formulas (16), (17), (18), (19), (20), (21), and (22). From the data thus obtained the following equations can be derived:

$$
\begin{aligned}
l_1 &= l_0 + k\delta_1, \\
l_2 &= l_0 + k\delta_2,
\end{aligned} \tag{24}
$$

where l_1 and l_2 are the measurement results of the half-wave sequence $n\lambda_e/2$, l_0 is the actual value of the half-wave sequence $n\lambda_g/2$; k is a dimensionless coefficient.

By solving (24) with respect to l_0 and k the value of the latter is determined. If the diffraction corrections δ_1 and δ_2 were accurately known, the value of k determined from the equation would be equal to 1, but since δ_1 and δ_2 are determined inaccurately, the value k will differ from unity.

A further improvement in the accuracy of δ can be attained in the following manner. A more precise determination of the electromagnetic field distribution in the mouth of the horn is difficult, and even if it were possible the volume of calculations for determining δ would be so vast that it would not be worthwhile. It is therefore, simpler to assume the dimensions of the horn aperture or that of the reflector slightly different from their actual values, i.e., to assume a certain effective value for the aperture and calculate from (16), (17), (18), (19), and (20) new values for δ_1 and δ_2.

By substituting in (24) the new values of δ_1' and δ_2', coefficient k is again determined. If it approaches unity very closely it means that δ_1' and δ_2' have been accurately determined.

The effective values of the aperture thus obtained for a given horn and mirror are used for subsequent calculations of the diffraction correction, in any position of the reflector with respect to the radiating horn.

It should be noted that (24) only holds providing l_1 and l_2 are measured with great precision. Since, however, the measurements of l_1 and l_2 are also subject to error, it is advisable to measure, for a more precise diffraction correction, the value of l_0 for more than two positions of the mirror, for instance, for 5-6 positions.

As the result of such measurements of l a system of nominal equations can be derived:

$$
\begin{aligned}
l_1 &= l_0 + k\delta_1, \\
l_2 &= l_0 + k\delta_2, \\
&\cdots \\
l_n &= l_0 + k\delta_n.
\end{aligned} \tag{25}
$$

The value k can then be determined with greater precision by solving these equations by means of the least-squares method, thus obtaining a more accurate diffraction correction.

SUMMARY

1. It is necessary to apply diffraction corrections if accurate measurements of various quantities by means of a radio-interferometer are required.

2. The above formulas for diffraction corrections provide their determination with an accurac; of about 6%.

3. A more accurate determination of the diffraction corrections can be obtained by means of their experimental evaluation for any particular equipment.

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A WAVEGUIDE POWER DIVIDER WITH AN ELLIPTICAL POLARIZATION

A. N. Akhiezer

Translated from Izmeritel'naya Tekhnika, No. 4, pp 50-52, April, 1960

The waveguide power divider described in this article is based on a new principle, consisting of the transformation of the original wave into an elliptically polarized wave H_{11} in a round waveguide and subsequent retransformation of the back to the H_{01} type in a rectangular waveguide.

The divider consists of two turnstile polarization converters connected by means of cylindrical section (Fig. 1). When oscillations are applied to branch A (or C) there arises in the cylindrical section an elliptically polarized wave whose polarization factor p (p') depends on the position of plungers 1 and 3 (5 and 7). The power division is determined by the ratio of p and p'. For a determined relation between the position of the plungers there is no coupling between branches A and B (C and D), i.e., the divider becomes a directional coupler. Moreover, the branches A, B, C , and D become matched.

Each converter represents a matched* turnstile connection [1] , whose side branches carry two shorting plungers. A unity amplitued wave entering branch 2 is divided in the following manner [2]: wave α enters the round waveguide at an amplitude $1/\sqrt{2}$ and two waves with amplitudes $1/2$ divide between branches 1 and 3. The waves reflected from the shorting plungers enter branches 2 and 4 and the round waveguide with polarization b. If the distances l_1 and l_2 from the junction center to the plungers satisfy the equation

$$l_2 - l_1 = \pm \frac{\lambda}{4}, \qquad (1)$$

where λ is the wavelength in the waveguide, then the reflected waves will cancel each other in branches 2 and 4 and add in the round waveguide,forming wave b with amplitude $1/\sqrt{2}$. The resulting oscillations in the round waveguide provide an elliptically polarized wave with a ratio of the elliptical half-axes ranging from 0 to 1, depending on the phase difference between the a and b waves.

In order to analyze the operation of the divider it is convenient to use the representation of polarization on Riemann's sphere [3]. For this purpose for each ellipse with an axes ratio r and a major-axis slope β, a corresponding point is found on the sphere with a place angle 2α and an azimuth 2β (Fig. 2), where $\alpha = \tan^{-1} r$. The points on the equator of the sphere corresponded to a purely linear polarization, and the north and south poles to the left-hand-side and right-hand-side circular polarizations.

Let us now use the proposition formulated in [3]. In the propagation between two elliptically polarized antennas the received signal is proportional to $\cos\ \delta$, where 2δ is equal to the distance between points M_1 and M_2 which represent on the sphere the polarization factors of the transmitting and the receiving antennas.** Thus the antennas, represented on the sphere by diametrically opposite points, is impossible, and with the mapped points coinciding it is maximum.

*A turnstile connection is considered to be matched if its standing-wave ratio on the side of any branch is equal to 1, when the remaining branches are terminated by matching loads.

**For one of the antennas (for instance the receiving) a conjugate complex of the polarization factor should be taken [3].

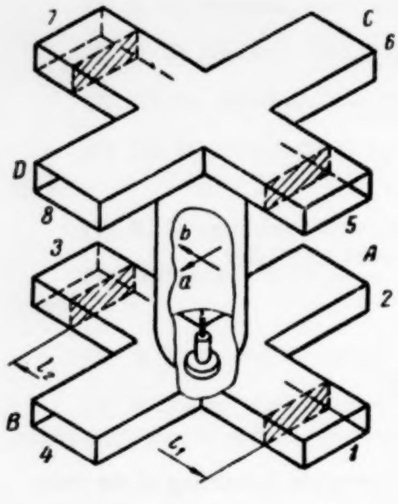

Fig. 1.

Reverting to the turnstile junction it is easy to see that the displacement of the mapping point over the sphere, providing (1) holds, takes place along the meridian $2\beta = \pi/2$. When any pair of plungers is displaced according to (1), 2δ varies between 0 and π and the power at the output of the divider varies between its maximum and zero. The transition from the cylindrical waveguide to two opposite branches C and D is represented on the sphere by two diametrically opposite points. Hence, the power in branches C and D varies according to the law $\cos^2\delta$ and the $\sin^2\delta$ and the division coefficient is equal to $\cot^2\delta$. The characteristic of the divider can be varied over considerable limits by introducing a relative angle of twist Θ between the two turnstile junctions. Figure 3 shows a family of characteristic curves for different angles Θ with the assumption that the top turnstile junction is tuned to linear polarization.

The operation of the divider was checked experimentally at 9375 Mc. In the turnstile junction standard rectangular waveguides were used 10 × 23 mm in cross section and round waveguides 24 mm in diameter. Before the divider was assembled the turnstile junctions were matched [1] by means of a device (Fig. 1), consisting of a piston, a thin plunger and a needle. Owing to the large difference in the diameters of the piston and the plunger, they provide a separate tuning for the round and rectangular waveguides. The plunger, which is parallel to the electrical lines of force in the rectangular waveguide, provides simultaneous matching of the turnstile junction from the direction of all the four waveguides, affecting but little the round waveguide matching which was attained by means of the piston. For precise matching the plunger is provided with a needle 0.5 mm in diameter and an experimentally selected length of 6 mm. Loads with a voltage standing wave ratio of 1.02 and 1.06 (in the round waveguide) were used for matching and the

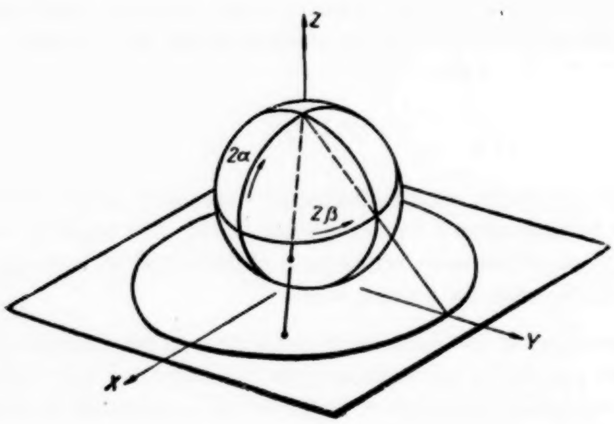

Fig. 2.

transition from the round to the rectangular waveguide had a voltage standing wave ratio $\ll 1.02$ (measured by the moving-load method).

After the assembly of the divider the turnstile junctions were adjusted for linear polarization by means of the following method.

Let us assume that the lower junctions has been adjusted approximately for linear polarization. Having connected to branches A and C an ultrahigh frequency generator and a detector, and to branches B and D matched terminations, we strive to obtain zero reading on the detector by moving plungers 5 and 7 and readjusting the position of plunger 3. Let the tuning correspond to points M_1 and M_2 in Fig. 4, which represents a cross section of the sphere (Fig. 2) by plane $2\beta = \pi/2$. By turning the top junction through 90°, which corresponds to an angle

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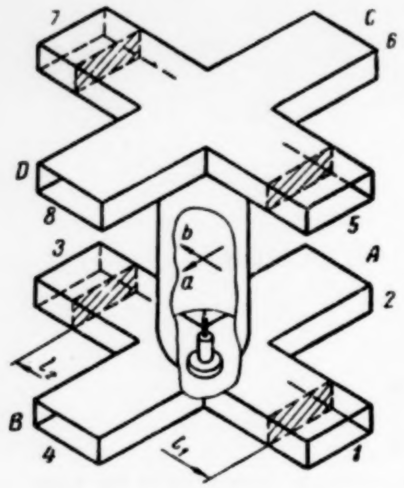

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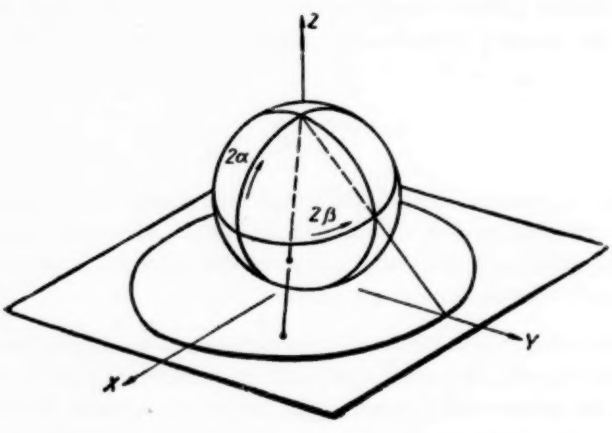

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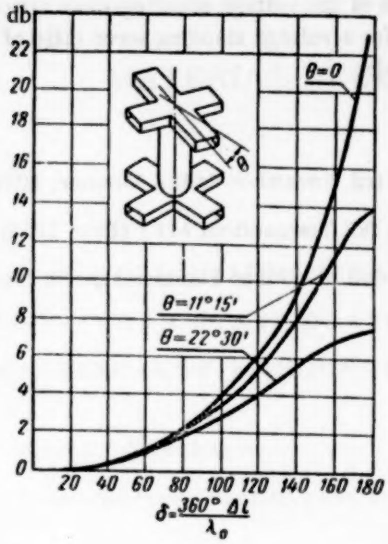

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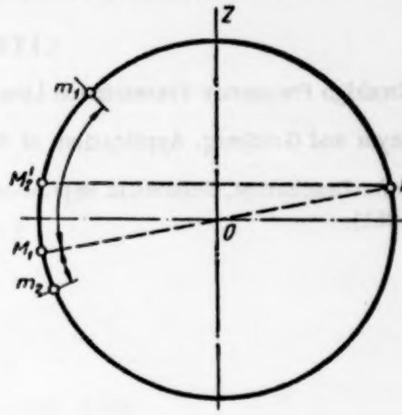

Fig. 4.

180° on the sphere, we transfer point M_2 to M_2'. We now find the displacement of plungers 5 and 7 required to make points M_2' and M_1 coincide. Moreover, in order to increase accuracy we use deviations $M_2'm_1$ and $M_2'm_2$ noting the reading of the detector proportion to $\cos(M_1m_1/2)$ and $\cos(M_1m_2/2)$. Next by means of linear interpolation the plunger is placed in a position which brings M_2' to the middle of the arc $M_2'M_1$. Then we return the top junction to its original position and correct the position of point M_1 by means of plungers 1 and 3 until a zero r reading is obtained on the indicator. If required the operation is repeated.

$l_1 = l_2 + \frac{\lambda_0}{4}$, mm	Power ratios, db		VSWR	Experimental value for directivity, db		Calibrated in db/0.01 mm
	experimental value	calculated value		N_{BC}	N_{BD}	
13	17.6	17.7	1.09	21.4	39.1	0.092
14	11.0	11.1	1.10	19.4	30.5	0.046
15	7.1	7.2	1.11	18.7	25.8	0.032
16	4.2	4.2	1.11	19.5	23.6	0.027
17	1.6	1.6	1.10	20.0	21.6	0.024
17.65	0	0				

Note: Initial loss of the divider is < 0.3 db.

The table shows some of the divider characteristics at 9375 Mc. The experimentally obtained power ratios $N_{CD} = 10 \log (W_C/W_D)$ where W_{CD} is the power in the corresponding branch determined by means of the substitution method with a reference attenuator of an accuracy of 0.1 db.

The above divider's power ratio depends on the frequency used, owing to the difference in the path of the reflected a and b waves. It manifests itself in the displacement of the initial position of the plunger scale with variations in frequency and amount in the experimental model to 0.09-0.2 db/Mc according to the set power ratio. This effect can be reduced to 0.03-0.07 db/Mc with minimum permissible distances of plungers to the center of either junction.

The frequency range of the divider is determined by the relation of the voltage standing-wave ratio and directivity to frequency. It has been established experimentally that for a voltage standing wave ratio of ≤ 1.25 and directivity > 15 db the frequency working range amounts to 400 Mc.

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MATERIAL RECEIVED BY THE EDITORIAL BOARD

FROM THE WORK EXPERIENCE OF THE ASTRAKHAN STATE CONTROL LABORATORY FOR MEASUREMENT TECHNIQUE

Yu. A. Cherkasov

Translated from Izmeritel'naya Tekhnika, No. 4, p. 53, April, 1960

The Astrakhan State Control Laboratory for Measurement Technique has organized jointly with the Council of National Economy a permanently acting seminar of workers in departmental control units, instrument maintenance bases, etc. Lessons are held not only in auditoriums, but even in factories and in the State Control Laboratory. Combined lessons with the representatives of various organizations and enterprises enable them to exchange experience and help one another with various problems.

Upon the initiative of Astrakhan State Control Laboratory, the technical management of the Council of National Economy has organized lessons for workers who operate and maintain instruments for thermotechnical measurements.

The Astrakhan Control Laboratory has asked the regional committee of the Party to establish Young Communist League Youth posts in petroleum depots for improvement in the accounting of expenditures of combustible and lubricating materials. All the losses eliminated go into the fund of the Young Communist League. Employees of the State Control Laboratory, when they go out into the district and the enterprises, conduct classes in keeping account of ,storage, and issuance of petroleum products.

All this work is occasionally made difficult by the fact that there are no graphic helps for the popularization of new measuring technique (pamphlets, posters, catalogs), in which new standards and instruments would be described, their comparative data given, and the means and methods of keeping account of combustible and lubricating materials would be clarified.

It should be required that enterprises beginning to issue approved standards or instruments publish an adequate printing of informational sheets and pamphlets in which the producing factory indicates the price of the instrument, gives a complete technical description and necessarily a drawing, gives data comparing it with other models, and shows the economic effect of introducing the given standard or instrument, indicating how the use of the new models will influence working conditions and accident prevention.

The State Control Laboratory for Measurement Technique will thus know in good time of the issuance into production of new standards and instruments and in turn will be able to inform interested organizations. In the long run this will enable the most rapid introduction of new measuring technique into the national economy.

ONE OF THE BASIC PROBLEMS – THE STRENGTHENING OF DEPARTMENTAL SUPERVISION

E. L. Perel'shtein

Translated from Izmeritel'naya Tekhnika, No. 4, pp 53-55, April, 1960

In recent months there has been a series of discussion articles in "Measurement Technique" about the organization of the measurement economy of industrial enterprises. The considerations stated in the articles are quite urgent. Experience suggests that these problems should be thrashed out and the corresponding rules formulated.

At the present time there still is not a single form of organization of the measuring establishment in enterprises. Undoubtedly, this is explained by the development of specificity in the enterprises, by the amount of apparatus in use, its complexity and variety.

In creating a modern technique and in introducing the newest technology into the various areas of the national economy, an important place is allotted to experimental research work, to the supervision and maintenance of equipment and processes, and this is nothing more than a broad application of efficient and true standards and measuring apparatus. From this proceeds the basic problem for one of the subdivisions of an enterprise, the assuring of the standard technical condition of the entire complex of standards and measuring apparatus in use. In that category is the organ of departmental supervision, the laboratory (plant) of control and measuring apparatus (KIP).

The KIP laboratory in the usual case consists of groupings by type of measuring equipment: measuring line-angle, electrical, radio, nonelectrical values, etc. The laboratory director should be responsible for the measuring establishment and the agreement of the standards and be absolutely subordinate to the management of the enterprise. The practice of designating "responsible" chief inspectors, mechanics and engineers is wrong, because these persons do not in practice have the necessary associations with measuring technique and are occupied with their own basic work. The expediency of combining all forms of standards and measuring equipment in a single laboratory does not give rise to any doubts – through it parallelism in work is done away with, operative efficiency in the solving of technical and organizational problems and the responsibility of technical personnel are raised, and the authority of the organ of departmental supervision as a single, independent section is increased. All this sharply improves the over-all technical condition of the measuring apparatus.

The duties of the KIP laboratory should be strictly defined and can be stated briefly as follows:

1. The accomplishment of inspection after utilization as designated; the proper use and maintenance of standards and measuring equipment of places of work; the elimination of inadequacies and raising the level of the operation of the equipment;

2. providing the departmental supervision with standard and nonstandard gauges and measuring equipment, with a record and analyses of the results and with subsequent working out of measures which raise the over-all technical level of the pool of measuring equipment;

3. the performance in individual cases of especially precise measurements using original means of verification;

4. the introduction and improvement of the necessary control facilities, and the working out of methods of especially precise measurement;

5. the provision of all types of repair of standards and measuring equipment (except linear and angular, issued in instrumental factories), the conduct of systematic preventive maintenance in necessary cases;

6. the systematization and study of the technical documentation, materials, catalogs, technical information, etc., relating to measuring equipment, in order to provide necessary recommendations in solving specific problems;

7. the maintenance of a central storeroom and for the formulation of rules regarding the measuring apparatus (apart from experimental instruments coming under the TsIS nomenclature).

Thus, there should be centralized in the KIP laboratory all the organizational and technical problems connected with the supervision of measuring equipment, its inspection and maintenance.

This miscellaneous, highly qualified activity requires the universalization of instrumentalists to assure the continuity of production.

The historic resolution of the Twenty-First Congress of the Communist Party of the Soviet Union and the June Plenum of the Central Committee of the Communist Party of the Soviet Union, the problems of automation facing our national economy in the near future, the introduction of advanced technology and new techniques, all these have profoundly affected all sections of production including measuring technique. The services of supervision, inspection, and maintenance are called on to meet all the demands of production for the introduction of advanced technology and the issuance of the newest forms of modern technique.

Unfortunately individual recommendations which emerge from discussion will hardly contribute to the strengthening of the organs of departmental supervision. Actually, to consider the service of supervision, inspection, and maintenance as "secondary" and to recommend the creation, on the basis of the organs of departmental supervision, of subsections, after the introduction of automation, at first glance, is a "progressive" suggestion: there will be here, on the whole, complex automation (and mechanization, of course), remote control, telemetry, the development of new measuring technique, applied electronics, and even supervision, inspection, and maintenance subdivisions for measuring equipment.

But a similar "reconstruction" of the enterprises contains serious deficiencies.

The introduction of a new technique in the national economy is not a temporary campaign but a difficult course broadly embracing all sections of production, touching upon all specialists, but primarily technologists, power engineers, and mechanics. The isolation of practical questions about new techniques from the entire productive complex, first of all, actually hinders the development of basic subdivisions of enterprises; secondly, it requires considerable additional resources and highly qualified cadres; thirdly, it virtually eliminates the organ of departmental supervision – its technical resources and cadres will in that case be considered as a reserve for the solution of problems of production, and the supervision, inspection, and maintenance will be put aside. There is no doubt that the director of the TsIL, who is responsible for the maintenance of the unity of standards, will give all his attention to new developments, studies of production, etc., because the management of enterprises usually watches this work carefully.

To sum up, neglected departmental supervision can "punish" the basic production and hinder the development of new technique.

It is stating the problem properly, if the organ of departmental supervision assures the fulfillment of the above-enumerated tasks, and all the problems connected with the introduction of new technique and the development of means of measurement are solved by the corresponding subsections: the services of the chief mechanic and power engineer, the technological and technical sections, the reconstruction sections, the research, and control-experiment sections and sections which usually have laboratories. But even productive and auxiliary factories, sections, and laboratories should not set to one side the solution of these problems.

In many enterprises some of the subsections mentioned are still not capable of studying new complex problems, and the individual directors of enterprises greet with satisfaction recommendations directed toward the adaptation of the organs of departmental supervision for these purposes.

There is an opinion that the organs of departmental supervision should deal first of all, not with measuring equipment, but with technical measurements, in whose execution there can be a number of "typical" inadequacies.

Thus, if measurements are made at values close to the limits and obsolete equipment is used, these problems will be within the competence of the organs of departmental supervision. But to bestow on the organs of departmental supervision the responsibility for the precision and adequacy of measurements assuring the most effective and reliable results in the solution of concrete problems, by a vast productive collective, means mechanically mingling the problems of the entire enterprise with the duties of the organ of supervision.

Organs of departmental supervision should assist the performance of technical measurements on an up-to-date level by providing necessary help to any specialist.

The idea of the need for the OTK to guide the organ of departmental supervision has become obsolete. The directors of the OTK cannot have close contact with the measuring establishment, and an excessive superstructure lowers the level of the operational work of the organ of departmental supervision. And the tasks of the OTK and the organ of departmental supervision are different. The automation of control is the task of the OTK, which solves these problems on the basis of plans of the organizational and technical measures in collaboration with the technical section and other subsections. The KIP laboratory makes necessary recommendations in this matter and certifies the completed arrangement.

The proper organization of the measuring establishment and well-established control on the part of the organs of joint supervision for local developments will enable avoiding enormous waste of resources and time on developments which are already being produced in series by other enterprises.

Not all the directors of enterprises daily look after the strengthening of the technical basis of the duty of supervision, inspection, and maintenance. The cause of this is basically a failure to understand the importance of the use of proper and true measuring apparatus. Underestimation of the work of the organs of departmental supervision can lead to very great troubles. This means that individual directors of production give little attention to the duty of supervision or often transfer it to enterprises assignments, diverting time from the fulfillment of basic functions even of organs of the Committee, which frequently show excessive softness, in spite of the unsatisfactory condition of the measuring equipment of the organs of departmental supervision.

It is time, at last, to apply reasonable and expedient order to the measuring establishments of industrial enterprises. One of the basic tasks of the organs of departmental supervision is the strengthening of an organizational and technical base capable of continuously providing production with serviceable and accurate measuring apparatus, of reliably assuring the attestation of nonstandard means of measurement and of rendering to other subdivisions technical help with their control and measuring equipment.

MOBILE VERIFICATION LABORATORIES

S. I. Berezhnoi

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To increase the productivity of labor of the state verifiers, the mechanization of work involving high labor cost, and the acceleration of the verification operations of the Stavropolsk State Control Laboratory for Measuring Technique, four GAZ-51 motor vehicles were equipped with mobile verification laboratories. As a result, verification work is being done at the place of use of the equipment in the districts and cities of the region and in the Kabardino-Balkar and Kalmyk ASSR.

With the help of such mobile verification laboratories a broad nomenclature of equipment is encompassed in temporary verification sections: automobile and stationary scales with a load capacity up to 25 tons, portable weights of all loads, ordinary and dial table weights, milk product, torsional, analytical and technical weights of classes I and II, spring balances, dynamometers, and machines for testing the mechanical properties of materials up to 50 tons, pendulum blocks, equipment for determining the hardness of metals, milk meter, gas and butter distribution columns, technical measuring tanks of classes I and II with a capacity up to 750 liters, technical and conventional third class standard weights, technical manometers up to 1000 kgf/cm^2, technical vacuum-meters and manovacuummeters of all systems, spring rods, smooth micrometers of all sizes, indicators of all types, indicating inside micrometers, slide gauges, depth measuring rods and surface gauges of all sizes, angle gauges, single-phase and triple-phase electrical meters, phase meters, ammeters, voltmeters and wattmeters of classes 1 and 1.5.

The equipment and standard weights for the verification of measures and measuring devices were placed in cabinets disposed on both sides and in the forward part of the body of the vehicle. A detachable workbench was mounted in the center of the vehicle between the cabinets and the equipment for verification arranged on it. In the middle of the body of the truck were fastened two special massive wooden cases on a survey table in the front of the truck-body and a second, somewhat removed from the first and with a seating arrangement. In the upper part of the truck-body, along its entire length, an I-beam was mounted with an easily moved trolley with rollers on it. A one-ton hoist was suspended on the trolley. The sturdy metal foundation of the truck body to which the I-beam was fastened enabled raising and lowering the half-ton standard weights. The reversible arrangement with an overhead crane mounted over the tail gate of the truck body enabled moving the weights on and off the truck without special arrangements, in working with the half-ton weights. Folding shelves were arranged on both sides of the cabinets and, in case of need, formed two semisoft divans. The passages between the cabinets and the special cases were used for the distribution of the portable and transportable verification equipment and devices.

The use of half-ton standard weights set in the motor vehicle and trailer reduced the time of verifying ten-ton weights by half, and 25 ton weights, by 25%. In addition there was less need to carry 20 kg weights.

THE EQUIPMENT OF MOBILE VERIFICATION LABORATORIES

V. A. Budzis

Translated from Izmeritel'naya Tekhnika, No. 4, p. 56, April, 1960

The Lithuanian State Control Laboratory for Measuring Technique utilizes GAZ-69 motor vehicles for the transportation of devices and equipment, which are removed from the motor vehicle and set up for work upon arrival at the place of work.

For this purpose, the laboratory has constructed removable working places in the form of stands with pedestals. A wiring system and clamps were mounted on the stands for the verification of electrical devices. A special table, and so forth were arranged for the fastening of the portable manometric press.

The standard devices necessary for verification were placed in the pedestals of the stands. To protect the equipment from damage when jolted, packing spaces were filled with microporous resin.

The state verifier, going out in a motor vehicle thus equipped, upon arriving at a place, can then and there start the verification operation without wasting time setting up the arrangements and looking for tables or other incidental furniture necessary for the fastening and mounting of the equipment.

The number of stands transported per motor vehicle can be changed, depending on the needs of verification in a given locality of this or that equipment. In periods between detached service the stands are used in the laboratory for current verifications.

The advantages arising from the use of the stands are obvious, since there is less need to keep equipment and devices used for travelling work in separate chests, which take up space; furthermore, and this is very important, the verification equipment is systematically and productively used in the work.

RAISING THE OPERATING QUALITY OF MEASURING DEVICES

N. S. Bychkov

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In the verification of measuring devices there are often encountered deficiencies in them which could easily be eliminated at the factories producing the devices and instruments, if the needs of the producers were better understood at those factories.

Micrometers produced by the "Kalibr" factory have ratchet springs that are too weak. From time to time the spring cannot create the necessary stresses even on new micrometers. After a short time the spring wears and becomes short. In a number of micrometers the surface of the micrometer screw is soft or has burrs along the diameter of the surface, which damages the thread of the nut of the micrometer screw when the latter is unscrewed.

The necessarily unsystematic correction of these deficiencies is costly and sometimes does not achieve its purpose.

The sliding gauge produced by the same factory – basically a good instrument – suffers from such deficiencies as the unscrewing and loss of the screw of the setting for a given dimension.

In manometers produced by the Tomsk factory (especially the oxygen type) the screw fastening the casing often becomes unscrewed and the casing dangles. A number of manometers were issued without pointer stops, which leads to pointer settings below zero.

Incorrect readings of the manometers are caused by poor fixing of the pointer on the axis.

Some factories issue hydraulic presses with manometers not protected against recoil. In these cases, the manometers get out of order on the second or third working day, and the production men often hold the manometer together with bolts which sometimes leads to rupture of the cylinder of else simply worsens the quality of the work of the presses.

Devices and instruments must be accurate, convenient, and reliable in operation.

REGULATING THE COSTS OF REPAIRING ELECTRIC METERS

N. V. Golikov

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Until the issuance of Instruction 195-54 of the Committee of Standards, Measures, and Measuring Devices, meters proceeded from the possessor directly to organs of the Committee, and only those meters which required more than preventive maintenance were repaired. In accordance with this, technical manuals of the Ministry of Communal Economy of the RSFSR were composed with a description of the repair of meters and an indication of its costs. Three types of repair were established: maintenance, current repairs and overhauling.

After the issuance of Instruction 195-54, every meter coming into use, before being subjected to the state verification, had to undergo preventive treatment and therefore had to go into the repair shops. In the manual of the Ministry of Communal Economy of the RSFSR, it was stated that the opening of the casing of a single-phase electric meter relates to current repairs. Since it is impossible to perform the preventive treatment (cleaning the meter mechanism and bearing) without opening the case, the result is that preventive treatment costs a customer from 39 to 55 rubles.

The price and description of the repairs were recorded and approved in the manuals at a time when the preventive treatment was not obligatory and only meters requiring repair were sent to the shops.

The ministry and department engaged in the repair of electric meters should therefore be required to review the technical manuals on repair and the preventive examination of meters.

INFORMATION

THE "ISOTOPES" EXHIBITION STORE

V. S. Merkulov and A. V. Klimushev

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In December, 1959, there was opened in Moscow (Leninskii Prospekt, 70/11), the "Isotopes" exhibition store of All-Union Office of "Isotopes" of the "Union-Reactive" Trust of the State Committee (Chemistry) of the Council of Ministers of the USSR.

The store handles orders for the issuable assortment of radioactive and stable isotopes, sources of nuclear radiation, and of radiation-shielding technique, and also serves as a demonstration and active propaganda center for introducing into the national economy control and measuring devices and methods based on the use of nuclear radiation.

Among the basic parameters measurable with radioactive methods of investigation are the total mass of a substance and the mass arriving on a unit of surface, the thickness of sheet material and film, the density, the level of free-flowing and liquid media, the concentration of various components and their distribution in subsequent systems, the consumption of a substance, etc. Methods using nuclear radiation are also utilized for counting piecework objects and the control of their geometric form. A specific singularity of these methods is lack of contact in making the measurements.

Our domestic industry is now issuing some tens of radioactive devices and equipment for the control and automation of technological processes.

The exhibition store has three sections: a section of control and measuring devices, one of isotopes and radiation sources, and one for shielding equipment.

In the control and measuring devices section,apparatus was exhibited which characterized certain basic directions in the utilization of isotopes and measuring technique in industry: a relay counter of items produced (RSP-11), level gauges for liquids and free-flowing bodies (RIU-1 and UR-6A), a liquid density meter (PZhR-2), an ionization manometer (MIR-3A), automatic fire alarm (ADI-1), various radiometric and dosimetric apparatus for alpha-, beta-, gamma-radiation and neutrons.

The radioactive counter of objects (model RSP-1) is intended for counting homogeneous objects on a conveyor or transporter. Up to 100 objects per minute can be counted with the RSP-11 model. The device is made up of standard blocks with which control of the geometric form and the dimensions of free-flowing pieces is practicable.

Level gauge RIU-1 is used for determining the limits of the demarcation of two media of different density (gas-liquid, liquid-solid body). The minimum difference in the mass of the substance in the path of the radiation assuring reliable operation of the level indicator is 20 g/cm^2. The permissible error of measurement is $\pm$ 2 cm; the period of operation is not more than two seconds.

The gamma liquid density meter PZhR-2 provides continuous remote measurement of the density of liquid within the limits of 1.0 to 1.5 g/cc. The time needed for the needle to traverse the entire scale of the device is eight minutes. The error of measurement does not exceed $\pm$5% of the value 0.5 g/cc.

The MIR-3A manometer (with alpha-emitter), whose principle of action is based on the measurement of current in an ionization chamber with a controllable gas, enables measuring the pressures of gases and water

vapors in the range from 0.01 to 10 mm Hg. The entire range divides into two sub-ranges, from 0.01 to 1 mm Hg and from 0.1 to 10 mm Hg. The error of measurement is ± 5% for each subrange.

Model ADI-1 equipment, which enters into the assembly of heat and smoke-collecting stations, assures the operation of signal apparatus upon the appearance of a light cloud of smoke in a locality.

The warehouse is expected to be filled with devices similar in purpose to those enumerated above and with devices intended for the measurement of a series of other parameters. Of these expected new devices, mention can be made of gauges of the thickness of sheet materials (ITU-495, ITSh-496, GT-150), film thickness gauges (BTP-1, ITP-476), and a potassium concentrate meter (RKK-B-1).

The beta thickness gauge ITU-495 is intended for automatic measurement of the thickness of a moving steel band on a rolling mill. The range of thickness measurements is from 0.03 to 1 mm. The instrument can be graduated for the measurement of the thickness of other materials in the range of 0.02 to 0.8 g/cm^2.

The film thickness gauge BTP-1 assures the measurement of the thickness of various films on a metallic backing. The range of the measurements is from 0 to 10 mg/cm^2. The relative error of the electronic part of the instrument is ±2%. The working principle of the instrument is based on measurement of the intensity of beta-radiation reflected by the control material. The instrument can be used for measuring the thickness of any films if they differ in atomic number from the backing material.

The potassium concentrate meter RKK-B-1 works on the principle of measuring the intensity of beta-radiation emitted by the natural radioactive potassium-40 isotope. The instrument enables determining, in ten to fifteen minutes, the calcium content in solutions with a concentration from 0 to 20% with an error of ±1.5%, replacing a complicated and lengthy process of chemical analysis.

Standard radiometric and dosimetric instruments are represented in the exhibition by the conversion instruments B-2, PS -10000 ("Floks"), PK-1000, universal radiometer TISS, a prospecting radiometer, model LUCh-A, sets of the individual dosimetric control KID-1, DK-0.2, etc.

Exhibits of finished products used in the construction of instruments whose work is based on radioactive methods were the industrial models of gas-discharge counters for the registration of alpha-, beta-, and gamma-radiations and neutrons, photoelectronic multipliers, and scintillators. Among the scintillators monocrystals were exhibited which included the inorganic – NaI (Tl), CsI(Tl), and KI(Tl) – and the organic – anthracene, toluylene, tolane, and naphthalene, with anthracene, and also plastic scintillators on a polystyrene base with various scintillating additives.

The isotopes and shielding-materials sections are intended basically to handle the question of organizations engaged in developing radioactive instruments and the application of isotopes to research purposes, and provide an immediate and operational link between the customer and the production enterprises.

It is possible, in the isotope and radiation-sources section, to enter orders both for isotopes prepared in the form of standard portions (packages) and for putting in ampoules sources of gamma radiations of various activities (thulium-170, iridium-192, cesium-137, cobalt-60, etc.), and also for ready sources of beta radiations in the form of discs and tablets (promethium-147, thallium-204, strontium-90 + yttrium-90, cerium-144 + praseodymium-144, ruthenium-106 + rhodium-106, etc). The activity of units of the surface of the various sources of beta-radiations can be reduced to 100 mcurie/cm^2. Samples of alpha-, beta- and gamma-emitters can also be ordered.

Among the means of shielding against penetrating radiation in the shielding-equipment section there are containers for the transportation and storage of gamma and beta preparations, cast-iron, and lead blocks, portable screens of lead glass, "instrumentaries" (a collection of hand manipulators) and lifting apparatus. To shield against contaminated liquid and powdered radioactive substances there were specimens of special clothing: pneumocostume LG-4, respirator ShB-1, gloves, over-sleeves, and semicoveralls.

In the same section, orders can be placed for samples of laboratory equipment and special chambers (chests). There is a demonstration, for example, of how to form properly a unisectional shielded chamber for one working-place for work with alpha-and beta-preparations in various forms. During work the chamber is kept under a vacuum of 20 mm of a column of water. The chamber is provided with exhaust ventilation, an observation window, supplying pipelines, mixing funnels, a collector of radioactive wastes, and gloves.

Exhibitions with various themes and consultations of qualified specialists will be held in the hall; popularized scientific films dedicated to the utilization of atomic energy for peaceful purposes will be shown. Reference materials and catalogs are on sale. Here one can become acquainted with the lastest attainments and new literary items in the field of the application of isotopes abroad.

The store accepts requisitions for radioactive preparations if the applicant has a special permit to work with radioactive substances.

CONFERENCE ON PROBLEMS IN RAISING THE LEVEL OF MEASURING TECHNIQUE AND THE QUALITY OF PRODUCTION

E. A. Gershkovich

Translated from Izmeritel'naya Tekhnika, No. 4, p. 59, April, 1960

In December, 1959, a conference was held of workers in enterprises of the Leningrad Council of National Economy. It was organized by the Technical-Economical Council of the Council of National Economy, the D. I. Mendeleev All-Union Scientific Research Institute of Metrology (VNIIM), by the provincial scientific-technical societies of mechanical engineering and instrument construction, and the Leningrad Hall of Scientific-Technical Propaganda.

The conference was devoted to the status and the means of raising the level of measuring technique, and of the supervision of the quality of production in enterprises of the Leningrad Council of National Economy.

In a report of Professor V. O. Arutyunov, director of the VNIIM, a survey was made of the technical means and methods of measurement at the various stages of production beginning with the quantitative and qualitative inspection of raw and semifabricated materials, the control of technological processes, and ending with the control of the finished product, at enterprises in various branches of industry of the Leningrad Council of National Economy (machine construction, textile, paper, chemical, food and other branches of industry).

Besides questions of the status of measuring technique and supervision itself, light was thrown in the report on the question of the organization of technical control in industrial enterprises of Leningrad. It was pointed out that the creation of a reliable and inexpensive system of control cannot be assured without a widespread utilization of the most modern means of measurement.

The participants in the conference observed that in recent years there has been a considerable increase in the equipping of factories and shops with means of control which in the past often were lacking in our enterprises or were encountered only singly. Nevertheless the existing level of measuring technique is not satisfactory enough In particular, in the metal-working enterprises of the Council of National Economy there are practically no means of active control of parts in the process of their manufacture. They are also poorly equipped with means of continuous control in the production process of enterprises of light industry.

The conference considered it necessary to direct the attention of the State Planning Commission of the USSR and the State Committee on Automation and Machine Construction to the inadequate extent of developments and of production of modern apparatus for continuous control of technological processes and for the control of the quality of production for the textile, paper, food, shoe-leather, pharmaceutical, and other branches of industry.

Along with this the conference noted that there are also great defects in the organization of the work of the technical control sections. The work of control apparatus is still not directed enough to the prevention of waste and to raising the technical level and reliability of the goods. The methods of mathematical statistics are not used in the organization of selective control and the methods of selective control bear an unsubstantiated character in most cases. The transition to inspectional forms of control is often made without any sort of clear analysis, and the performance of the article at the consumer level is poorly studied.

In the resolution of the conference, mention was made of the need for organization in the staff of the central apparatus of the Leningrad Council of National Economy as regards special inspection of the quality of

products. The staffs of the measurement laboratories of the enterprises should also be reinforced.

The conference considered it necessary to recommend that the Technical Administration of the Council of National Economy, in conjunction with the VNIIM and other research and planning organizations, develop measures for the equipping of enterprises with modern means of measuring, packing, and follow-up of materials, goods in process and finished goods, for control of the conduct of the technological processes and the quality of production. Special attention should be directed toward the elimination of subjective methods of evaluation.

The conference pointed out the need for the organization of a central base in Leningrad, a factory for the repair of instruments of quite varied types.

Considerable improvement is required in providing spare parts and a blueprint to enterprises who utilize a measuring instrument.

The participants in the conference drew the attention of the Committee of Standards, Measures, and Measuring Instruments to the need for speeding up the development and approval of standards for methods of statistical analysis and control of the quality of production, and also to the need for the expansion and strengthening of the verification laboratories of VNIIM.

In connection with the fact that individual sections of "Locations of Technical Control Sections" are obsolete, the conference suggested reviewing this condition and bringing it into correspondence with present requirements.

SECTIONAL CONFERENCES OF WORKERS OF THE STATE CONTROL LABORATORIES FOR MEASURING TECHNIQUE

Translated from Izmeritel'naya Tekhnika, No. 4, pp 59-60, April, 1960

In 1960, the administration of the authorized Committee of Standards, Measures, and Measuring Instruments in the Council of Ministers of the USSR held sectional conferences of the workers of the State Control Laboratories in Krasnodar, Kuibyshev, Gor'kii and Voronezh, in which there are Class I State Laboratories. The basic purpose of the conferences included organization of the exchange of experience between the State Control Laboratories regarding such knotty problems of their activity as the composition of a plan for the years 1960-1965, the planning and organization of verification and control-inspection work, the organization of departmental supervision and of the basic laboratories, etc.

Participating in the conference, which was held at the Kuibyshev State Control Laboratory, were the directors of the State Control Laboratories at Orenburg, Penza, Saratov, Stalingrad, Tatar, and Ul'yanovsk, as well as the managers of the interregional sections of those laboratories.

The participants in the conference became acquainted in detail with the organization of the verification and control-inspection work of the laboratories, with the verification equipment and its condition, with the technical verification of a series of instruments. The director of the Kuibyshev State Control Laboratory informed the participants in the conference about a plan of measures worked out for the next two years in order to make effective the resolution of the June Plenum of the Central Committee of the Communist Party of the Soviet Union with regard to measuring technique in the territory served by the State Control Laboratory.

Discussion of organization of the planning and follow-up of operational work in the laboratory made it possible for the participants in the conference to understand these problems better.

Those at the conference became acquainted in detail with the organization of departmental supervision at a large industrial enterprise and with the work of the base laboratory for the repair and adjustment of instruments for linear-angle measurements.

The participants in the conference noted that the sectional conference produced a benefit, since as a result of detailed acquaintance with the work of the Kuibyshev State Control Laboratory they saw the strong and weak sides of the work of that laboratory.

The exchange of work experience by the participants in the conference will undoubtedly contribute to improvement of the activity of the laboratory and the interregional sections.

Taking into account the positive results of the conferences that have been held, the administration of the authorized Committee of Standards, Measures, and Measuring Instruments in the Council of Minister of the RSFSR plan to organize similar conferences in Chelyabinsk and Jaroslaw.

THE FOURTH CONFERENCE ON PRECISION INSTRUMENT BUILDING

V. A. Egorov

Translated from Izmeritel'naya Tekhnika, No. 4, p. 60, April, 1960

On January 12-14, 1960, the Fourth Conference on Precision Instrument Building was held in Dresden (the German Democratic Republic); it was organized by the German Society of Engineers and Technicians and the Department of Precision Instrument Building of the Technical Institute (Dresden).

Three hundred delegates participated in the work of the conference. In addition to delegates from East German industry, there were representatives of Austria, Hungary, China, Poland, the USSR, West Germany, and Czechoslovakia.

At the two plenary sessions 13 reports were read on various problems of precision instrument construction. The third day of the work of the convention was devoted to becoming acquainted with the enterprises and scientific research institutes of Dresden. At the place where the conference was held, there was an exhibition of optical and weight measuring instruments, calculators, and typewriters, as well as models of instruments of the future.

R. Hegner (the University of Graphic Arts, Berlin), in his report "Form and Instruments," noted that very serious attention must be given to the form of instruments. Improvement in technical quality of an instrument should be accompanied by improvement in its esthetic form. New forms of telephone apparatus, geodetic instruments, photographic apparatus, etc., were demonstrated. The principal attention was directed here to the beautiful external shape of the instrument; the color is bright, the shapes soft and oval. A small display was devoted to this theme, in which specimens of models of future instruments were exhibited.

In a report of Z. Markert (Technical University, Dresden) the results were presented of investigations of the influence of temperature on the operation of electrical measuring instruments. The parts of instruments are usually made of different materials and coatings which have different coefficients of linear expansion, and therefore during heating they act in different ways upon the operation of sensitive mechanisms in an instrument and not infrequently are a source of errors of measurement, On the basis of investigation of different designs of conduits in electrical instruments the best forms of them were demonstrated.

The report of V. Yants (Institute of Instrument Construction, Berlin), was devoted to the technique of gluing parts and the testing of glued parts for stability. Data were given for mechanical and electrical properties and also for the chemical action of epoxy resins used for gluing parts in the serial production of precision instruments.

As a result of the investigations the usefulness of utilizing epoxy resins in low volt and vacuum technique was proved, especially in electrical instruments and in chambers impenetrable by gas.

In the report of K. Kholochek (Technical University, Vienna) the results were given of experimental research on the use of molybdenum sulfide as an additive to lubricating liquids.

The report of S. Hildebrand (Technical University, Dresden) reviewed the schemes of various bearings used in construction of precision instruments and also the interaction of the conditions arising in bearings.

The report of V. Gro (Jena) was basically devoted to the standardization of external parts of optical instruments at the Karl Zeiss factories in Jena.

The report of R. Lehman (Institute of Instrument Construction, Berlin) gave the principles of construction of air bearings, which are sliding bearings in whose clearance air is compressed to about six atmospheres, forming an air layer. Thus, in air bearings the lubricating layer is a thick layer of air which preserves the entire bearing surface. It is necessary to note as deficiencies of air bearings that, first, the bearing surfaces must have very little roughness (on the average, purity of Class 12 or 13) and, second, the air must be carefully filtered. During the report, models of air bearings were demonstrated, as well as the use of an air layer in the transportation of heavy equipment during their setting or processing on a bench.

The use of air bearings has enabled high rates of rotary movement to be obtained, up to 80,000 rpm, and in some cases up to 100,000 rpm during an operating period of up to four hours.

M. F. MALIKOV

Translated from Izmeritel'naya Tekhnika,
No. 4, p. 61, April, 1960

On February 16, 1960, Professor Mikhail Fedoseevich Malikov, Doctor of Technical Sciences, the most eminent Soviet metrologist and an Honored Worker of Science and Technique, died at the age of 78 after a long illness.

The name of M. F. Malikov, the creator of the Soviet school of metrologists, is well known both in the USSR and abroad, but it is especially near and dear to all workers of the system of the Committee of Standards, Measures, and Measuring Instruments.

When he finished at the University of Petersburg in 1910, Malikov started working in the electrical section of the Central Bureau of Weights and Measures – now the D. I. Mendeleev All-Union Scientific Research Institute of Metrology,-where he performed the duties of a laboratory assistant, laboratory manager, acting director of the scientific part, and manager of the metrological section.

As a result of intense work by Malikov, the first state standard ohm and volt in Russia were created. In this work he brought to life his new idea of group standards, for the first time in international practice. His work in the area of precise electrometry provided a measurement of electrical values with an accuracy that was the maximum for that time.

A brilliant experimenter, he was also a talented designer and himself designed both mercury standards and original electrical resistance coils. He proposed a new design of standard cells and developed instruments to determine mechanically the volume of bodies of rotation and other instruments.

Malikov took an active part in international metrological work. The first international comparisons of electrical standards were made upon his initiative.

His many years of experience in the field of metrological work were reflected in his principal work, "Principles of Metrology," which he began before the war and finished during the severe 90-day siege of Leningrad. This original work, which is still the reference book of every instrument builder, was dedicated by him to his successors – the young Soviet metrologists and workers in the factories of measuring technique. Malikov was also the author of more than 60 scientific papers.

He took an active part in work on normalization and standardization. He was the author of the basic metrological standards concerning terminology, classification and determinations in the field of measures and measuring instruments. With his participation and under his supervision standards, were developed in connection with systems of units of measurements, as well as a large number of terminological

standards embracing various areas of science. Special mention should be made of his work on the creation of verification schemes, which have entered profoundly into the practice of verificational activity.

Malikov was a member of the Commission on Scientific and Technical Terms and Definitions of the All-Union Committee on Standardization in the Council of Work and Defense, was an active member of the Commission on Units of Measures in the technical section of the Academy of Sciences of the USSR.

Malikov taught much, transmitting his rich experience, in particular, in lectures on metrology at the Leningrad Institute of Precise Mechanics and Optics in the Leningrad Polytechnical Institute. Because of his talent and exceptional industry he became one of the most eminent theoreticians of metrology, a brilliant experimenter and a leading scientific worker of the State Bureau of Weights and Measures.

Malikov was honored with four governmental awards.

A large school of Soviet metrologists was created by the work of M. F. Malikov, and this is the best guarantee of the success of Soviet metrology, a matter to which the deceased devoted his long and fruitful life.

IN THE COMMITTEE OF STANDARDS, MEASURES AND MEASURING INSTRUMENTS

CONFERENCE ON PROBLEMS OF STANDARDIZATION AND NORMALIZATION OF INSTRUMENT BUILDING

Translated from Izmeritel'naya Tekhnika, No. 4, pp 62-63, April, 1960

On February 10, 1960, a conference on problems of standardization in instrument building was held at the Committee of Standards, Measures, and Measuring Instruments in the Council of Ministers of the USSR.

Present at the conference were the chairmen of the State Committee of the Council of Ministers of the USSR on branches of the national economy, the chief engineers and managers of the standardization and normalization sections of scientific research institutes of instrument building and design offices, and representatives of enterprises of the instrument-building industry.

The purpose of the conference was to discuss the question of the status and tasks of further development of work on standardization and normalization in the field of instrument building, and the exchange of experience with this question.

A report on the direction of work on standardization and normalization in instrument building and on measures for improvement of the work in the area of the state standarization and normalization was made by the substitute for the representative of the Committee of Standards, Measures, and Measuring Instruments, G. D. Burdun.

His report clarified the status and tasks of standarization in the area of instrument building. On January 1, 1959, there were 305 standards in effect regarding measuring instruments. The plan of work for 1959 called for the development and review of 45 standards; 45 standards were actually approved by the Committee. For 1960, 59 standards are projected for development, of which 20 are in the nature of revisions of existing standards.

There are 53 standards of linear-angular measurements, 50 standards for the optical-instrument group, 36 for instruments that measure temperature, 21 for electrometrical instruments, and 12 for instruments which measure time.

Work on standardization is developing slowly in some important areas of instrument building, in particular, on instruments for automatic control and regulation, radiometric instruments, instruments for the measurement of ionizing radiation and computers.

Delay in the introduction of approved standards should be noted as a serious obstacle, as should the long periods required for the acceptance by industry of the output of some instruments with advanced characteristics established by the corresponding standards. Thus, the introduction of a State Standard (GOST) for resistance thermometers is delayed, the delivery by industry of instruments for the measurement of cylindrical gears of wheels according to GOST 5368-58 has not been organized, etc.

To accomplish the task set by the June Plenum of the Central Committee of the Communist Party of the Soviet Union regarding standardization of large-scale production, it is necessary to bring into existence a complex of work on the development of standards for instruments widely used in the national economy.

To assure the most rapid introduction of automation there must be development of single aggregate unified systems of control and regulation of the parameters of the production processes and also of the measuring and regulating elements such as data units, converters, secondary instruments, and operating mechanisms entering these systems.

The needs which arise from the broad development of specialization and consolidation in industry present anew the question of basic improvement of work on the unification and normalization of monotypic parts, assemblies and articles for the purpose of eliminating their unjustified differences in type.

In 1959 a series of standards for parts and assemblies was adopted, and in 1960 this work will be expanded. Plans call for the creation of standards and normals for data units, amplifiers, operating mechanisms, regulators, primary and secondary instruments for measuring temperature, pressure, discharge, level, and analysis of instruments of aggregate-unified systems, thermocouples, sylphons, tension members for electrometric instruments, prisms for weight-measuring instruments, etc.

The role and responsibility of the basic organizations for standardization and normalization are rarely raised, in the light of the tasks imposed, obligatory tasks, placed on the 18 leading scientific research and engineering planning organizations and enterprises, with firmly established types of production set for them.

It is necessary that these organizations really become scientific-technical centers in the field of standardization and normalization on the types of production required of them and that they be responsible for: the fulfillment of their duties as regards the development of plans for standards and normals; the coordination of work by the enterprises and scientific research and planning organizations for the development of those plans; the execution of scientific research and experimental work connected with the development of standards and normals; the preparation of proposals for a review, at an opportune time, of the characteristics of the state standards and normals not meeting current requirements.

The Committee of Standards, Measures, and Measuring Devices has developed and coordinated with corresponding organizations a standard position regarding the basic organization on standardization and normalization and a standard position regarding organs of standardization and normalization in Councils of National Economy, enterprises and organizations.

The basic organizations should fully utilize the rights given them in bringing about control of the development, introduction, and observance of state standards and normals, and should systematically put this work in practice in organizations connected with the planning and production of the corresponding forms of production.

Control of the maintenance of standards and technical conditions is of great importance. In 1959 the Committee of Standards, Measures, and Measuring Devices conducted a verification of the maintenance of standards at 23 instrument-building enterprises.

During the year,control was exercised on the quality of weight-measuring instruments and dial indicators, rotary gas meters for industrial use, instruments for testing hardness, testing machines, ordinary and technical thermometers,alcohol meters, saccharometers, optical and radiational pyrometers, heat recorders, manometers, differential manometers, manometric thermometers, and also radiometric and dosimetric apparatus.

Steps were taken regarding materials of control, directed toward the elimination of any deficiencies discovered. Some of those steps were taken at the time of control, and this made it possible to remove deficiencies at once on the spot.

In conclusion, the report clarified the measures for further development and improvement of the matter of standarization and normalization in the area of instrument building and of increase in the quality of industrially produced instruments.

The representatives of many of the basic organizations presented a communication explaining the working experience of the basic organizations on standardization and normalization in instrument building.

The chief designer of the Special Design Office of standardization and normalization of the Central Scientific Research Institute of Complex Automation, Comrade Chervyakovskii, explained the work of his organization. Speaking of the work of basic organizations, he pointed out the necessity for improvement in the coordination of work of the basic organizations upon standardization and normalization. In questions of standardization of the means of automation a first-order task is the creation of state standards for the initial and final parameters and the technical characteristics of interconnected means of automation, assuring their ability to form complexes together and their interchangeability. Unification of systems of automation is a very important task.

Comrade Pokrovskii, in his report, dwelt on questions of standardization of radiometric instruments and directed attention to the need to develop standards for elements of radiotechnical instruments, waveguide flanges, coaxial joints, transformers, choking coils, etc.

The manager of the standardization and normalization section of the All-Union Scientific Research Institute of Electrometric Instruments, Comrade Bochkov, described the measures taken in electrometric technique. A plan was presented for the standardization of assemblies and parts of instruments being standardized in the next 2-3 years.

The director of the standardization and normalization section of the Office of Interchangeability in the metal-working industry, Comrade Doschatov, explained the activity of the office upon standardization in the area of instruments for linear and angular measurements in machine building.

Comrades Bystrova, Nadezhdin, Arrisson, Kozlov, Meshcheryakov, Zhukovskii, Dvoretskii, Geidysh, and Zaks, who participated in the conference, directed attention, in their addresses, to deficiencies in the development of standards and normals and in the organization and coordination of this matter; they offered a number of suggestions on the further development of this work and the improvement of the activity of the basic organizations for standardization and normalization in instrument building.

I. New Normative Documents on Measures and Measuring Instruments Approved by the Committee

New Standards (upon registration in February, 1960)

State Standard 6400-60. Manometers and vacuummeters, spring control. Replaces State Standard 6400-52.

State Standard 6507-60. Micrometers with 0.01 mm graduation. Replaces State Standard 6507-53.

State Standard 6521-60. Manometers and vacuummeters, spring models. Replaces State Standard 6521-53.

State Standard 8623-60. Electrometrical instruments. Interchangeable supplementary resistance. Technical specifications. Replaces State Standard 8623-57.

State Standard 8711-60. Ammeters and voltmeters. Technical specifications. Replaces State Standard 8711-58.

State Standard 9376-60. Instruments for control of dimensions of parts in process of being worked into surface-grinding machines. General types. Technical specifications. First issuance.

State Standard 9377-60. Points, diamond, for measuring hardness by the Rockwell and Vickers methods. First issuance.

State Standard 9378-60. Specimens of roughness of surface (working). Technical specifications. First issuance.

State Standard 9384-60. Universal instruments for measurement of inside dimensions. General technical specifications. First issuance.

State Standard 9392-60. Levels, frame and bar, for machine construction. Replaces State Standards 3053-45 and 3308-46.

State Standard 9375-60. Calibers for thread of geological exploration drilling tubing with nipple connection. Tolerances and technical specifications. First issuance.

New Instructions for the Verification of Measures and Measuring Instruments (upon registration in February, 1960

Instruction 185-60 on the verification of direct current shunts.

II. Instructions in the Method of Verifying Measures and Measuring Instruments, Approved by the Administration of Measuring Instruments of the Committee

Methodical instructions No. 176 on the processing of profilograms of roughness of surface.

Methodical instructions No. 177 on the verification of sample and working dosimetric instruments intended for use in measuring the strength of dose x-ray radiations in the range of tension of 80-200 kv.

III. Measures and Measuring Instruments Approved by the Committee on the Basis of Their State Tests and Permitted for Use in the USSR

Telescopes, radiational, compensating, for pyrometers with factory label PRK-600, for measurement limits of 700 to 1800°C (with glass optic), Ministry of Construction, RSFSR. State Catalog No. 1299-59.

Inductance box with factory label R-546, Kiev Council of National Economy. State Catalog No. 1300-59.

Ammeters, portable, with factory label D-533, Kiev Council of National Economy. State Catalog No.. 1301-59.

Voltmeters, portable, with factory label D-533, Kiev Council of National Economy. State Catalog No. 1302-59.

Wattmeters, portable, with factory label D-533, Kiev Council of National Economy, State Catalog No. 1303-59.

Equipment with factory label KV-2 for verification of electronic voltmeters, Estonian Council of National Economy. State Catalog No. 1304-59.

Saccharometers, type E, with 0.05% graduations, Moscow Regional Council of National Economy. State Catalog No. 1305-59. Combined with saccharometers entered in the State Catalog under No. 817.

Direct current meters with factory label D-600-M, Leningrad Council of National Economy. State Catalog No. 1306-60.

Ammeters, switchboard, with factory label M-366, Krasnodar Council of National Economy. State Catalog No. 1307-60.

Voltmeters, switchboard, with factory label M-366, Krasnodar Council of National Economy. State Catalog No. 1308-60.

Ohmmeters, portable, with factory label M-372, Krasnodar Council of National Economy. State Catalog No. 1309-60.

Modulation meters with factory label IM-20, Gor'kii Council of National Economy. State Catalog No. 1310-60.

Wattmeters, small cosine, portable, with factory label D-542, Kiev Council of National Economy. State Catalog No. 1311-60.

Ferrometer for testing magnetic materials, with factory label U-542, Kiev Council of National Economy. State Catalog No. 1312-60.

Wattmeters, portable, recording, with factory label N-379, Krasnodar Council of National Economy. State Catalog No. 1313-60.

Ammeters, portable, recording, with factory label N-371, Krasnodar Council of National Economy. State Catalog No. 1314-60.

Voltmeters, portable, recording, with factory label N-371, Krasnodar Council of National Economy. State Catalog No. 1315-60.

Ammeters, portable, recording, with factory label N-380, Krasnodar Council of National Economy. State Catalog No. 1316-60.

Voltmeters, portable, recording, with factory label N-380, Krasnodar Council of National Economy. State Catalog No. 1317-60.

Voltmeters, portable, modification D57/7, with upper limits of measurement 50-75-150 v, Kiev Council of National Economy. State Catalog No. 963-60. Combined with previously approved portable voltmeters with factory label D57. State Catalog No. 963.

Amperevoltmeters, portable, recording, with factory label N370-M, Krasnodar Council of National Economy. State Catalog No. 1201-60. Combined with previously approved portable recording amperevoltmeters with factory label N-370. State Catalog No. 1201-58.

Amperevoltmeters, portable, recording, with factory label N370A-M, Krasnodar Council of National Economy. State Catalog No. 1202-60. Combined with previously approved portable recording amperevoltmeters with factory label N-370A. State Catalog No. 1202-58.

Scales, platform, movable weights, with factory label VPG-3(m), Severo-Kazakhstan Council of National Economy. Catalog No. 1205-60. Combined with movable platform scales with factory label VPG-1(m) and VPG-2(m). State Catalog No. 1205-59.

IV. Measures and Measuring Instruments Eliminated from the State Catalog

(from March 1, 1960)

Wattmeters, portable, ASTD. State Catalog No. 206.

Voltmeters, portable, ASTV. State Catalog No. 208

Ammeters, portable, MK-60. State Catalog No. 242.

Voltmeters, portable, MK-60. State Catalog No. 243.

Ammeters, switchboard, MK-55. State Catalog No. 244.

Voltmeters, switchboard, MK-55, State Catalog No. 245.

Voltmilliammeters, portable, MK-60. State Catalog No. 247.

Ammeters, portable AST. State Catalog No. 322.

Oscillograph, electronic, ÉO-4. State Catalog No. 347.

Ammeters, portable, LM-1. State Catalog No. 374.

Voltmeters, portable, LM-1. State Catalog No. 375.

Voltmeters, portable, LM-3. State Catalog No. 376.

Ammeters, switchboard, É-16. State Catalog No. 379.

Microammeters, portable, LM. State Catalog No. 398.

Millivoltmeters, portable, LM. State Catalog No. 399.

Ammeters, portable, ÉLA. State Catalog No. 408.

Voltmeters, portable, AMV. State Catalog No. 410.

Voltmeters, switchboard, É-110, State Catalog No. 416.

Ammeters, switchboard, É-12. State Catalog No. 417.

Wattmeters, portable, ÉDV. State Catalog No. 489.

Scales, instrumental, PR-500. State Catalog No. 573.

Oscillograph, electronic, ÉO-5. State Catalog No. 636.

Forceps, electrometrical, KÉ. State Catalog No. 685.

Voltmeters, portable, ÉLV. State Catalog No. 803.

Wavemeters, heterodyne, VG-526, VG-527, and VG-528. State Catalog No. 1122-57.

(From April 1, 1960):

Manometers, differential, ring, telemetric, DKÉV, DKÉR. State Catalog No. 771.